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## Investment booms, diverging competitiveness and wage growth within a monetary union: An AB-SFC model

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# **Investment booms, diverging competitiveness and wage growth within a monetary union: An AB-SFC model**

**Bernhard Schütz**

**July 2022**

# Investment booms, diverging competitiveness and wage growth within a monetary union: An AB-SFC model

Bernhard Schütz\*

## Abstract

This paper proposes a 2-country stock-flow consistent agent-based model of a monetary union and exposes it to three supposed drivers of imbalances in the build-up to the Great Recession: unequal developments in investment, competitiveness and wages. The model has some innovative features: It does not rely on given propensities to import, with agents from different regions instead all being part of the same market and import shares emerging endogenously as a result of the geographical distance between agents. The model also features labor hoarding by firms and a banking sector that bears some Minskyan features. The model is able to replicate the low unemployment rates in the North that were paralleled with falling unemployment rates in the South together with trade imbalances in favor of the North.

JEL CLASSIFICATION NUMBERS: E12, E20, F45

KEYWORDS: stock-flow consistent agent-based modeling, monetary union, international imbalances, investment, productivity, wages

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# 1 Introduction

The financial crisis of 2007-2008 had a major impact on Eurozone economies. Particularly the southern part of the Eurozone was hit quite hard: Rising investment due to initial optimism about the catch-up prospects of the Southern countries was accompanied by private sector financial deficits and foreign financial inflows, leading to rising indebtedness of the private sector (e.g. [Chen \*et al.\*, 2013](#); [Kalemlı-Ozcan \*et al.\*, 2010](#)). At the same time, relative losses in international competitiveness (e.g. [Gräbner \*et al.\*, 2020](#)) and higher nominal wage growth compared to other Eurozone countries (e.g. [Schmitt-Grohé & Uribe, 2013](#)) contributed to the deterioration of the current account and the build-up of financial deficits.

In what follows, we want to take a closer look at how these factors contribute to the emergence of international imbalances and crises. While other authors have already used simulation models to look at these factors, they usually focus on a single factor without including the other ones.<sup>1</sup> In contrast, this paper proposes a model framework in which all three of these factors are analyzed in an integrated way.

For this purpose, we develop a 2-region agent-based stock-flow consistent model of a monetary union that will subsequently be exposed to the kind of developments mentioned above: unequal developments in investment, competitiveness and wages. Stock-flow consistent modeling ensures that every outgoing flow is matched by a corresponding incoming flow. Furthermore, it also keeps track of all stock developments, making sure that every financial asset is matched by a financial liability. In other words, it creates model consistency by ensuring that all in- and outflows as well as all financial assets and liabilities add up to zero (see e.g. [Godley & Lavoie, 2007b](#)). Agent-based modeling complements the strengths of stock-flow consistent models by adding the additional dimension that all patterns observed at the aggregate level emerge from individual interactions between a multitude of heterogenous agents (for a more detailed discussion see e.g. [Caiani \*et al.\*, 2016](#)).

The specific model that is proposed here possesses some innovative features: First, it does not rely on given propensities to import. Instead, agents from different regions are all part of the same market, with import shares emerging endogenously as a result of the geographical distance between agents. Furthermore, it also features labor hoarding by firms as well as a banking sector that bears some Minskyan features.

The paper is structured as follows: section 2 provides an overview of the existing literature. Section 3 offers a description of the model, while section 4 presents the results of the various simulation scenarios. The final section offers some concluding remarks.

## 2 Literature

A number of authors have addressed the topic of international imbalances within stock-flow consistent (SFC) and agent-based stock-flow consistent (AB-SFC) models. Among the SFC approaches, [Belabed \*et al.\* \(2018\)](#) use a 3-country SFC model calibrated to match the US,

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<sup>1</sup>For an analysis of competitiveness see [Duwicquet & Mazier \(2010\)](#), [Mazier & Valdecantos \(2014\)](#), [Dawid \*et al.\* \(2018\)](#) and [Gräbner \*et al.\* \(2022\)](#). For different wage growth regimes see [Greenwood-Nimmo \(2014\)](#) and [Caiani \*et al.\* \(2019\)](#). [Gräbner \*et al.\* \(2022\)](#) come closest by discussing investment booms and diverging competitiveness, but do not take into account different wage dynamics.

China and Germany in order to analyse the impact of changes in income distribution and debt-financed consumption on current account imbalances. A regions's imports are a function of total consumption demand in that region, depending on exogenous import propensities. Households receive income through a distributional process in which each decile of the household sector receives a certain share. Consumption depends on consumption of those in the next highest income decile, where households are assumed to finance a fixed proportion of their consumption through loans. Banks accommodate household credit demand up to a certain leverage rate. Once that leverage is reached, credit supply is restricted.

Godley & Lavoie (2007a) propose a 3-country SFC model that anticipates some problems the Eurozone would face in the post-2007 period. In their model two countries share a common currency, whereas the third country has a flexible exchange rate with the other two (which is compared to a Germany-Italy-USA scenario). The authors abstract from firm investment and initially assumes exogenous government spending. Analyzing a situation in which the Italian import propensity for US goods increases, they predict that this leads to a decline in Italian GDP and a deterioration of its trade balance. The US would enjoy temporarily higher GDP, but would revert towards its initial level once trade flows have led to an appreciation of the Dollar. Germany, on the other hand, would experience a higher level of GDP as its exports would profit from a weaker Euro. Hence, the trade balance of the country with the floating exchange rate would revert into a balanced position, whereas the trade balance of the countries within the currency union (because the exchange rate is fixed between them) would not. Additionally, the model predicts that the Italian fiscal balance would follow a downward trajectory, whereas the German fiscal balance would be on an upward trajectory. Assuming that the ECB is not willing to absorb these bills and that their increasing supply is reflected in rising interest rates, this quickly destabilizes the model as it makes the Italian position unsustainable. On the other hand, adjusting government spending, such that the level of debt is not increasing, eliminates trade balances, but comes at the price of a large drop in Italian GDP.

Duwicquet & Mazier (2010) propose a 2-country SFC model which looks at the potentially stabilizing impact of cross-boarder ownership of financial assets. They find that when one country experiences a decline in competitiveness (expressed by a rise in its import propensity) or domestic demand, a rise in the dividend payments received through the ownership of firm shares from the other region stabilizes income and demand.

Mazier & Valdecantos (2014) propose a 4-country SFC framework (US, Germany, Spain, rest of the world). Whereas Germany and Spain share the Euro, the rest of the world is assumed to have a fixed exchange rate with respect to the Dollar. The Euro/Dollar exchange rate is determined by the relative supply and demand of bonds denominated in Euros to the US. Fiscal policy is subject to a deficit rule. The authors simulate a loss in Spanish competitiveness with respect to non-EMU countries and an even larger loss with respect of Germany (signified by corresponding increases in its import propensities). They find a negative effect on Spanish GDP that is matched by positive effect on German GDP, so that the effect averages out within the EMU. The corresponding net effect on the two external regions is hence zero. Mazier & Valdecantos (2015) proceed by analysing different hypothetical Euro settings, including restoring national currencies (and letting them coexist with the Euro) and Germany leaving the Eurozone.

They find that both measures, by allowing for an exchange rate adjustment, have a stabilizing impact. [Mazier & Valdecantos \(2019\)](#) in turn simulate the adaptation of the monetary union to Keynes' original concept of an international clearing union with the Bancor as a common currency, also finding that it promotes stability.

[Greenwood-Nimmo \(2014\)](#) present a 2-country SFC model with an endogenous exchange rate between them that builds on [Godley & Lavoie \(2007b, ch. 12\)](#). Inflation is determined by conflict over wage setting. It is assumed that the propensities to consume out of income and wealth are negatively influenced by the real interest rate. The authors look at the performance of a range of interest rate targeting policies and fiscal policies in particular situations. They look at the events of an exogenous fall in exports, an increase in wage growth and a change in taxes happening in only one of the regions, and find that a mix of fiscal and monetary policy responses has a higher stabilizing impact compared to only a monetary policy response.

Finally, [Gräbner \*et al.\* \(2022\)](#) provide an SFC model of a monetary union consisting of two regions (North and South) that also trade with the rest of the world. It is assumed that import demand from the rest of the world is exogenous. Each of the two regions features a Minskyan banking sector that relaxes its margin of safety in times of perceived stability and rapidly increases it in times of distress. They show how an investment boom in one region leads to boom-bust cycles that also transmit into the other region. They also show that a decline in Southern competitiveness (which materializes as a rise in the import propensity from the rest of the world) does not automatically lead to increased borrowing from the North, but rather a rise in central bank debt. The South only starts to get indebted with respect to the North once it is assumed that the North conducts successful mercantilist policies (represented by a rise in Northern exports to the rest of the world), since these developments increasingly leave Northern banks with a surplus of reserves. They also illustrate the stabilizing impact of the central bank acting as lender of last resort and governments conducting counter-cyclical fiscal policy.

Among those authors who have proposed AB-SFC models, [Caiani \*et al.\* \(2018\)](#) present a multi-country AB-SFC model that looks at the impact of different fiscal rules (in terms of fiscal deficit to GDP allowances) within a monetary union. Abstracting from household debt, they only model credit to firms. Fiscal spending is modeled as lump sum transfers to households. Furthermore they abstract from capital and capital goods producing firms and assume that production takes place with labor only. They show how stricter fiscal rules lead to lower economic growth, employment and higher instability. The model accounts for innovation through either R&D or imitation. Households allocate their demand between tradeables and non-tradeables in fixed proportions. The model assumes that consumer preferences and the varieties offered by firms are randomly allocated on a circle ([Salop, 1979](#)). Consumers rank products according to its proximity to their preferences and its price. They find that when they include a higher number of countries, fiscal austerity leaves economies with even higher public debt.

[Caiani \*et al.\* \(2019\)](#) build on [Caiani \*et al.\* \(2018\)](#) and analyse the impact of different wage growth regimes. They find that higher wage growth occurring in one country leads to a deterioration of its trade balance and its economic growth performance in the short run. In the long run, however, it leads to higher productivity growth and an economic recovery. On the other hand, when wages rise in all countries, GDP and productivity growth increase in all countries.

Cardaci & Saraceno (2017) show within a 2-country model how in the presence of consumption emulation effects and the availability of consumer credit, rising inequality gives rise to boom-bust cycles and current account imbalances within a monetary union. Thereby, a certain share of household demand is satisfied through imports, with this share being a function of the relative prices of domestic and foreign goods.

Dawid *et al.* (2018) use the EURACE model and assume two regions differing in their size and their initial level of technology. Their model assumes a single capital good firm which produces different vintages of capital with distinct productivities. Workers in turn need specific skills in order to be able to work with a certain vintage of capital. Analyzing a scenario in which one region has more capital and workers with a higher level of skills, they find that subsidies that provide an incentive for firms in the poor region to adapt more advanced production methods are more effective than income transfers to households, even when the latter is financed by the union.

While the above authors have referred to single factors contributing to the emergence of international imbalances in the Euro area prior to the Great Recession, including investment booms (Gräbner *et al.*, 2022), competitiveness (Dawid *et al.*, 2018; Duwicquet & Mazier, 2010; Gräbner *et al.*, 2022; Mazier & Valdecantos, 2014) and wages (Caiani *et al.*, 2019; Greenwood-Nimmo, 2014), none of these models has discussed all three of these features within a single framework. Gräbner *et al.* (2022) come closest, by discussing investment and competitiveness, but do not take into account diverging wage dynamics.

Moreover, in contrast to most of the models above dealing with international imbalances, the model does not rely on import propensities. Instead, agents from different regions are all part of the same market and import shares emerge endogenously through the distance between the different agents. In this respect it is closely related to Caiani *et al.* (2018), who assume that the space of household preferences can be modeled as a circle, with each household's preferences taking a spot on that circle, and households allocating spending between tradeable and non-tradeable goods in fixed proportions.

Furthermore, unlike the international agent-based models discussed above it offers an explicitly Minskyan perspective (Minsky, 1986).<sup>2</sup> In a Minskyan tradition, banks assess the maximum size of a loan that an agent will be able to repay, applying among other things an endogenous margin of safety. If clients nevertheless become unable to repay, banks conduct insolvency and liquidation procedures.

Finally, in contrast to the models discussed above, the model features labor hoarding, i.e. firms that are reluctant to hire and fire workers immediately.

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<sup>2</sup>For a detailed survey of models that stand in a Minskyan tradition see Nikolaidi & Stockhammer (2017). Open economy models with an explicit Minskyan background have been provided by Foley (2003), Gallardo *et al.* (2006), Kohler (2019) and Gräbner *et al.* (2022). Among these approaches, the model in Gräbner *et al.* (2022) comes closest to the model used in this paper, as it accounts for the possibility of bankruptcy, credit rationing by banks as well as fiscal policy. However, none of these models are agent-based. For a more detailed discussion see Gräbner *et al.* (2022).

**Figure 1:** Distance between agents: regions  $r$  are represented by parallel lines with  $distance_r$  in between them



(a) Distance between agents in same region

(b) Distance between agents in different regions

### 3 Model

#### 3.1 Initial conditions and geographical setup

The model consists of two identical regions, which are comprised of one government, a large number of households, banks, firms producing consumption goods and firms producing investment goods. Furthermore the two regions share a common central bank. All agents within a region are located along a line in order to reflect the fact that some agents within the region might find themselves more on the periphery than others. The two lines representing the regions are parallel to each other, the distance between them being  $distance_r$ . The distance between agents is taken as the sum of the horizontal and vertical distance (see figure 1). At the beginning, ownership of firms and banks is allocated to the household living closest to them, where we assume that each bank and firm is owned by one household. In case that the closest household already owns a firm or a bank, ownership goes to the next closest household.

Geographical location plays a central role in the decision of agents. In particular, we build on the well established fact that, in analogy to the force of gravity, distance has a negative effect on trade (see e.g. Carrère *et al.*, 2020). In order to reproduce the stylized fact that domestically produced goods make up a substantial share of total purchases of agents, we assume that agent  $i$ 's perception of the attractiveness  $a$  of a good  $y$  produced by firm  $f$  is influenced by the geographical distance ( $distance_{i,f}$ ) relative to the total size of the region and its price  $p_{f,r,t}$ :

$$a_{f,r,t}^y = \mu_y \cdot \frac{distance_{i,f}}{size_r} + (1 - \mu_y) \cdot p_{f,r,t} \quad (1)$$

where  $\mu_y$  represents the relative weight. This affects the purchase of consumption goods by households as well as the purchase of capital goods by firms and governments. Preferences for locally produced goods can be explained by regional producers being more adapted to regional needs and tastes. Another potential explanatory factor is ethnocentrism (Shimp & Sharma, 1987), which denotes the feeling of loyalty towards or moral obligation to buy from local producers (see e.g. Balabanis & Diamantopoulos, 2004; Watson & Wright, 2000). See on this also



Dawid *et al.* (2018).

In the case of governments we assume that they are omnipresent within their region, meaning that they do not have a specific location within their region (all domestic producers are similarly close to the government), so only the distance between the regions plays a role. This means that governments have a general tendency towards domestic producers but not for specific domestic producers.

When households and firms apply for loans and banks decide between interbank loan offers, the attractiveness of an offer is calculated in a similar way: Agent  $i$ 's perception of the attractiveness  $a$  of a loan offer  $o$  by bank  $b$  is influenced by the geographical distance ( $distance_{i,b}$ ) as well as the offered interest rate  $i_{b,r,t}^o$ :

$$a_{b,r,t}^o = \mu_L \cdot \frac{distance_{i,b}}{size_r} + (1 - \mu_L) \cdot i_{b,r,t}^o \quad (2)$$

where  $\mu_L$  represents the relative weight.

Model consistency demand that any financial asset must be matched by a financial liability. Therefore, the starting deposits of households ( $D_{h,r}$ ) and firms ( $D_{f,r}$ ) as well as the initial equity deposits of banks ( $D_{b,r}$ ) are created by way of the government selling bonds to the central bank and distributing the proceeds to the private sector accordingly.<sup>3</sup>

### 3.2 Order of events

The following enumeration gives an overview of the order in which events take place:

1. Banks adjust margins of safety
2. Firms form sales expectations, negotiate wages, make investment plans, hire workers, produce output, pay workers and set prices
3. Firms estimate their financial needs, apply for bank loans and adjust investment plans if necessary
4. Governments makes investment decisions, estimate financial needs and issue government bonds
5. Banks try to acquire the necessary amount of reserves on the interbank market; if they cannot get sufficient reserves at the interbank market, they borrow them from the central bank; afterwards, banks purchase the newly issued government bonds
6. Banks pay interest on private deposits, collect interest on negative deposits and collect debt payments on private sector loans
7. Central bank pays interest on reserve deposits and collects interest on CB loans
8. Governments pay interest on bonds and repay those bonds that have reached maturity
9. Consumption and capital goods firms deliver their goods to the market

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<sup>3</sup>See on this also Caiani *et al.* (2018) who use a similar procedure.

10. Governments adjust social security benefits
11. Households determine consumption demand
12. Households, firms and governments buy goods on the goods market
13. Unsold products are returned to the inventories of their producers; firms pay VAT to the government
14. Banks collect debt payments from insolvent agents
15. Firms calculate and distribute profit; update of firm capital stock
16. Banks set interest on credit and calculate and distribute profit
17. Firm and bank owners make labor supply decision
18. Central bank calculates and distributes profits
19. Budget balance of governments gets calculated
20. Firms and households with negative deposits apply for credit
21. Banks clear interbank balances; banks join the interbank market; central bank provides credit if necessary; government claims against banks are settled

### 3.3 Firms

Following [Caiani \*et al.\* \(2016\)](#), firms adaptively adjust their sales expectations ( $s_{r,t}^e$ ) each period. In line with [Caiani \*et al.\* \(2018\)](#) we also take into account that firm sales can fall short of initial expectations because the firm ran out of goods to sell. In such a situation they would not reduce their sales expectations. Therefore, when sales in the previous period fell short of expected sales, but the firm managed to sell its entire inventory ( $inv_{f,r,t} = 0$ ), expectations are not adjusted downward.

$$s_{f,r,t}^e = \begin{cases} s_{f,r,t-1} & \text{if } s_{f,r,t-1} < s_{f,r,t-1}^e \wedge inv_{f,r,t} = 0 \\ s_{f,r,t-1}^e + \lambda \cdot (s_{f,r,t-1} - s_{f,r,t-1}^e) & \text{otherwise} \end{cases} \quad (3)$$

where the subscripts  $f$  and  $r$  denote the individual firm and the geographical region in which it is located respectively.

Desired output follows from sales expectations. In particular, firms want to produce the amount that they expect to sell ( $s_{f,r,t}^e$ ) plus some buffer stock ( $\nu \cdot s_{f,r,t}^e$ ) minus the inventory left over from the previous period ( $inv_{f,r,t-1}$ ) (see [Caiani \*et al.\*, 2016](#)):

$$y_{f,r,t}^D = s_{f,r,t}^e \cdot (1 + \nu) - inv_{f,r,t-1} \quad (4)$$

If a firm finds itself in the process of liquidation, desired output becomes 0 as the firm stops producing.

Similar to [Caiani \*et al.\* \(2016\)](#), firm potential output ( $y_{f,r,t}^*$ ) is given by the capital stock inherited from the previous period ( $k_{f,r,t-1}$ ) and exogenous capital productivity  $\kappa$ . However, whereas in their model only consumption goods firms need capital, while capital goods firms use only labor, in our model both types of firms need capital.

$$y_{f,r,t}^* = \kappa \cdot k_{f,r,t-1} \quad (5)$$

Labor demand ( $N_{f,r,t}^D$ ) can subsequently be calculated as

$$N_{f,r,t}^D = u_{f,r,t}^D \cdot \frac{k_{f,r,t}}{l_{k,r}} \quad (6)$$

where  $l_{k,r}$  denotes the exogenous capital-labor-ratio and  $u_{f,r,t}^D$  the desired rate of capacity utilization defined as (see again [Caiani \*et al.\*, 2016](#))

$$u_{f,r,t}^D = \min \left( 1, \frac{y_{f,r,t}^D}{y_{f,r,t}^*} \right) \quad (7)$$

The number of additional workers needed ( $N_{f,r,t}^{new}$ ) is equal to the difference between labor demand ( $N_{f,r,t}^D$ ) and the size of its current staff ( $N_{f,r,t-1}$ ). We assume that firms offer only full time jobs, which means that the demand for new workers is always rounded upwards to the nearest integer. Furthermore, the model takes into account labor hoarding. In particular, we assume that firms do not dismiss workers immediately, but only once  $N_{f,r,t}^{new}$  has been negative for three consecutive periods. If that is the case, firms adopt a cautious firing policy by dismissing only those workers that have been effectively surplus within these three periods, i.e.  $\Delta N_{f,r,t} = \max(N_{f,r,t-2}^{new}, N_{f,r,t-1}^{new}, N_{f,r,t}^{new})$  (the maximum implying that firms choose the least negative number). The same applies for the opposite: since workers that are deemed surplus are not disposed of quickly, firms also adopt a cautious approach to hiring new workers: they only hire new workers once the number of additional workers needed ( $N_{f,r,t}^{new}$ ) has been positive for three consecutive periods. If that is true, they will again create only those new positions that have been in demand for each of these periods, meaning that  $\Delta N_{f,r,t} = \min(N_{f,r,t-2}^{new}, N_{f,r,t-1}^{new}, N_{f,r,t}^{new})$ . The demand for additional workers can of course only be realised in full if sufficient unemployed workers ( $U_{r,t}$ ) are available ( $U_{r,t} \geq \Delta N_{f,r,t}$ ). In cases when a firm is insolvent and has therefore lost access to credit, it can only employ the number of workers that it can afford with the remaining amount on its deposit.

Firms produce output using capital and labor, where

$$y_{f,r,t} = \min(N_{f,r,t} \cdot l_{k,r} \cdot \mu K, y_{f,r,t}^*) \quad (8)$$

Wage setting is taking place once a year (i.e. once every 12 periods) through collective wage bargaining, where we assume that the outcome is influenced by the rate of inflation experienced over the previous year ( $\pi_{r,t-1,t-12}$ ) as well as the average rate of unemployment over the course of the year ( $u_{r,t-1,t-12}$ ). More specifically, the bargaining power of workers ( $b$ ) is given by

$$b_{r,t} = b_1 \cdot (u_r^{ref} - u_{r,t-1,t-12}) \quad (9)$$

where  $u_r^{ref}$  denotes the reference rate of unemployment against which actual unemployment is judged against. Changes in collective wage agreements are hence given by

$$\Delta w_{r,t} = \max(w_{r,t-1} \cdot (\pi_{r,t-12,t-1} + b_{r,t}), 0) \quad (10)$$

where we assume that worker representatives would never agree to a nominal wage cut.

Investment demand is determined by the desired growth rate of the capital stock ( $g_{f,r,t}^D$ ), which depends on the deviations of the rate of utilization of the capital stock ( $u_{r,t-1}$ ), the rate of return ( $r_{f,r,t-1}$ ) from their respective normal rates ( $\bar{u}$ ,  $\bar{r}$ ) (see [Caiani et al., 2016](#)) and the rate of depreciation of capital  $\delta$  (as firms take into account that part of the capital stock will depreciate over the current period) according to

$$g_{f,r,t}^D = \gamma_1 \cdot \frac{u_{f,r,t-1} - \bar{u}}{\bar{u}} + \gamma_2 \cdot \frac{r_{f,r,t-1} - \bar{r}}{\bar{r}} + \delta \quad (11)$$

where  $r_{f,r,t-1} = \Pi_{f,r,t-1}/k_{f,r,t-1}$  and  $\Pi_{f,r,t}$  denotes the net profits of the firm. Capital goods are produced by capital good firms, whereas consumption goods are produced by consumption good firms. Capital good firms deliver these capital goods to the market, where firms are able to buy them. Firms enter the market in random order and buy amount  $n$  (or less if remaining demand for capital goods or the remaining supply of the producer are smaller than  $n$ ) from the capital goods producer whose offer they find most attractive. In successive rounds firms buy capital goods until all firms have satisfied their investment demand or the market runs out of supply. The acquired capital goods ( $I_{f,r,t}$ ) will be added to the capital stock inherited from the previous period ( $k_{f,r,t-1}$ ) taking into account the rate of depreciation  $\delta$ :

$$k_{f,r,t} = k_{f,r,t-1} + I_{f,r,t} - \delta \cdot k_{f,r,t-1} \quad (12)$$

Firms distribute net wages to workers and pay the labor income tax directly to the government. The model abstracts from a progressive wage tax and instead assumes a uniform proportional tax rate  $\tau_r^w$ .

Firms set prices as a mark-up ( $mu_{f,r,t}$ ) on unit labor cost ( $labor_{f,r,t}$ ) ([Caiani et al., 2016](#)). Consumption goods firms also have to factor in a value added tax ( $\tau_{r,t}^{va}$ ). Prices of consumption ( $p_{f,r,t}^c$ ) and capital goods ( $p_{f,r,t}^k$ ) are therefore given by

$$p_{f,r,t}^c = (1 + mu_{f,r,t}) \cdot \frac{labor_{f,r,t}}{y_{f,r,t}} \cdot (1 + \tau_{r,t}^{va}) \quad (13)$$

$$p_{f,r,t}^k = (1 + mu_{f,r,t}) \cdot \frac{labor_{f,r,t}}{y_{f,r,t}} \quad (14)$$

The mark-up is subject to constant revision by firms: Whenever inventories ( $inv_{f,r,t-1}$ ) are below desired inventories (which constitute a share  $\nu$  of expected sales  $s_{f,r,t}^e$ ), firms interpret this as a sign that their goods are in high demand and raise their mark-up by a factor  $\rho_f$ . Contrary, when firms are left with inventories above the desired level, they will try to get rid of some of that inventory by reducing that mark-up vice versa (see here [Caiani et al., 2016](#)). If inventory corresponds to desired inventory, the mark-up is kept constant.<sup>4</sup>

<sup>4</sup>This is a little different to [Caiani et al. \(2016\)](#), who assume that firms also raise the mark-up when inventories

$$mu_{f,r,t} = \begin{cases} inv_{f,r,t-1} < \nu \cdot s_{f,r,t}^e : mu_{f,r,t-1} \cdot (1 + \rho_f) \\ inv_{f,r,t-1} > \nu \cdot s_{f,r,t}^e : mu_{f,r,t-1} \cdot (1 - \rho_f) \\ inv_{f,r,t-1} = \nu \cdot s_{f,r,t}^e : mu_{f,r,t-1} \end{cases} \quad (15)$$

Finally, if a firm is in the process of liquidation and has unsold inventories, it will reduce its price each period by  $\chi$  until all inventories are sold.

Before firms enter the market for capital goods, they assess their financial situation and apply for credit if expected funds needed exceed their existing funds. If it turns out that they cannot secure enough credit from banks, they reduce their demand for capital goods in order to make due with the financial resources they have.<sup>5</sup>

Firm gross profits  $R_{f,r,t}^{gross}$  are equal to

$$R_{f,r,t}^{gross} = rev_{f,r,t} + INT_{f,r,t}^D - labor_{f,r,t} - VAT_{f,r,t} - INT_{f,r,t}^L - \delta \cdot k_{f,r,t-1} \cdot \bar{p}_{r,t}^k \quad (16)$$

where  $rev_{f,r,t}$ ,  $INT_{f,r,t}^D$ ,  $labor_{f,r,t}$ ,  $VAT_{f,r,t}$ ,  $INT_{f,r,t}^L$ ,  $delta$ ,  $k_{f,r,t-1}$  and  $\bar{p}_{r,t}^k$  denote sales revenues, interest on deposit, labor costs, value added tax payments, interest on loans, the capital depreciation rate, the capital stock and the current average price of capital.

Firms have to pay the corporate tax rate  $\tau^c$  on (positive) gross profits, yielding net profits

$$R_{f,r,t}^{net} = R_{f,r,t}^{gross} - \max(\tau^c \cdot R_{f,r,t}^{gross}, 0) \quad (17)$$

Firms use that profit to meet their debt repayment obligations ( $repay_{f,r,t}$ ). Furthermore we assume that firms want to hold a certain financial buffer  $D^{min}_{f,r,t}$ , which is equal to a share  $\psi_f$  of current labor cost, on their deposit. Those who receive profit income have to pay an income tax rate  $\tau^r$ , which is kept by the firm and distributed to the government. Hence firms distributed profits are equal to

$$R_{f,r,t} = (1 - \tau^r) \cdot \max(R_{f,r,t}^{net} - repay_{f,r,t} - D^{min}_{f,r,t}, 0) \quad (18)$$

if  $D \geq \psi_f \cdot labor$ , while distributing only share  $\tau_f$  if that minimum liquidity target is not met:

$$R_{f,r,t} = (1 - \tau^r) \cdot \tau_f \cdot \max(R_{f,r,t}^{net} - repay_{f,r,t}, 0) \quad (19)$$

are exactly at their desired level and use past sales  $s_{f,r,t-1}$  instead of expected sales to get desired inventories.

<sup>5</sup>The expected financial needs of the firm are the sum of expected expenditures for debt payments, capital goods, distributed profits and taxes (corporate tax and VAT) minus expected sales revenues, interest income and the existing amount on its deposit ( $D_{f,r,t-1}$ ). Debt payments from the previous period are taken as a proxy for expected debt repayments. Expected payments for capital goods are calculated as current investment demand multiplied by the average price of capital goods  $\bar{p}_{r,t}^k$ . Expected profits, distributed profits and interest income are determined via an adaptive expectations process similar to equation 3. Expected sales revenues are equal to sales expectations multiplied by the firm's current price  $p_{f,r,t}$ . Expected VAT payments follow straightforward from expected sales revenues, while expected corporate tax payments follow from expected profits.

### 3.4 Households

Household consumption depends on an autonomous part ( $c_0$ ), disposable income and net wealth ( $NW_{h,r,t}$ ) according to

$$C_{h,r,t}^D = c_0 + c_1 \cdot \frac{W_{h,r,t} + INT_{h,r,t} + R_{h,r,t}^e}{\bar{p}_{r,t}^c} + c_2 \cdot \frac{NW_{h,r,t}}{\bar{p}_{r,t}^c} \quad (20)$$

where  $W_{h,r,t}$ ,  $INT_{h,r,t}$ ,  $R_{h,r,t}^e$  and  $\bar{p}_{r,t}^c$  denote wage income, interest income, expected profit income and the average price of consumption goods. However, if the household is insolvent, its consumption is limited to the poverty line (with all remaining income going to debtors):

$$C_{h,r,t}^D = POV_{r,t}$$

Firms deliver consumption goods to the market, where households are able to buy them. Households enter the market in random order and buy amount  $n$  (or less if remaining demand for consumption goods or the remaining supply of the producer are smaller than  $n$ ) of the product they find most attractive.

Households who own firms or banks initially do not join the labor force. However, if received profit income and remaining savings falls below the level of social security benefits  $trans_{g,r,t}^{soc}$  (see further below), they also join the labor force. In the latter case, if they get hired by a firm next period, they receive wage income  $W_{h,r,t}$ , otherwise their unemployment status will get them access to social security benefits  $trans_{g,r,t}^{soc}$ . If profit income and savings rise above social security benefits, the owner leaves the labor market again.

### 3.5 Governments

Each government has a deposit at the common central bank and finances itself through tax income and by issuing bonds. At the beginning of each period, the government makes investment plans. Each period, governments demand an autonomous amount of capital goods ( $g_0$ ) as well as an additional amount equal to a share of real GDP in the previous period. In order to allow for a certain degree of automatic stabilizers, this share depends on the gap between current unemployment and the government's reference unemployment rate ( $u_g^{ref}$ )

$$G_{r,t}^D = g_0 + g_1 \cdot (u_{r,t} - u_g^{ref}) \cdot Y_{r,t-1} \quad (21)$$

where  $Y_{r,t-1}$  denotes real GDP.<sup>6</sup> Similar to firms, governments buy these goods on the market for capital goods.

Afterwards, the government estimates its financial needs for the current period and issues the corresponding amount in government bonds.<sup>7</sup> Government bonds are bought by banks, where

<sup>6</sup>In the literature different functions for government spending have been proposed. In Keen (1995) government spending depends on changes in the unemployment rate. Greenwood-Nimmo (2014) assume that government spending depends on the deviation of inflation from the government's target rate. In Nikolaidi (2014), government expenditure increases when banks raise their margins of safety and falls in the opposite case. Kapeller *et al.* (2018) and Gräbner-Radkowsch *et al.* (2022) assume that governments raise fiscal spending whenever the private sector becomes credit-constrained.

<sup>7</sup>Expected financial needs of the government are the sum of expected automatic expenditures (spending on unemployment, social security benefits and interest payments), expected investment expenditures, upcoming debt repayments and desired financial reserves minus the amount of existing reserves on its central bank deposit. Desired financial reserves are a ratio  $\psi_g$  of expected financial needs. Expectations on unemployment and social

we assume that all banks buy the same amount. Government bonds mature after  $\xi_g$  periods. Governments pay interest  $i_g$  each period and repay the entire principle at the end. Furthermore the government is subject to a deficit rule, specifying that its fiscal debt is not supposed to be larger than 3% of nominal GDP. If the expected fiscal deficit for the current period exceeds this threshold, the government reduces its investment demand accordingly.<sup>8</sup> If the government runs out of financial means within the given period, it becomes unable to pay benefits. In this case the government will try to satisfy these payments in the next period, adding them to next period's expected financial needs.

Governments adjust benefit payments once a year (i.e. once every 12 periods). Households that have been unemployed not more than 6 periods receive unemployment benefits  $trans_{h,r,t}^u$ , which are equal to share  $\tau_u$  of the maximum wage earned within the last six periods. Those who have been unemployed for longer receive social security benefits  $trans_{g,r,t}^{soc}$ , which is set with respect to the poverty line in the respective region according to  $trans_{g,r,t}^{soc} = \tau_{soc} \cdot POV_{r,t}$ . The poverty line is defined as 50% of the current median household income in the corresponding region. Social security benefits are adjusted once every 12 periods.

The government budget balance is given by

$$BB_{r,t} = T_{r,t}^{VA} + T_{r,t}^w + T_{r,t}^c + T_{r,t}^r + R_{g,r,t}^{CB} - TRANS_{r,t} - G_{r,t} \quad (22)$$

where  $T_{r,t}^{VA}$ ,  $T_{r,t}^w$ ,  $T_{r,t}^c$ ,  $T_{r,t}^r$ ,  $R_{g,r,t}^{CB}$ ,  $TRANS_{r,t}$  and  $G_{r,t}$  denote total receipts of value added taxes, taxes on wage income, corporate profits and profit income, received central bank profits, paid transfers (unemployment and social security) and government expenditure on capital goods.

### 3.6 Banks

Payments between banks, governments and banks, the central bank and banks as well as between the central bank and the government are settled through reserve deposits located at the central bank. Banks acquire the needed reserves on the interbank market, where banks with excess reserves lend to banks with demand for reserves. In case that banks cannot entirely satisfy their demand on the interbank market, they acquire the missing reserves by borrowing them directly from the central bank.

Households and firms settle their payments through their bank deposits. If the respective counterparts have their deposits at different banks, these payment flows have to be matched by a corresponding flow of reserves between the banks.<sup>9</sup> These obligations are not settled immediately. Instead, each bank keeps track of the claims that arise from these flows. At the end of the period, banks net out their claims against each other and only transfer these net obligations (respectively receive their net claims).

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security spending are formed by an adaptive expectations formation process similar to equation 3. Expected investment expenditures are equal to its demand for capital goods multiplied by the current average price of capital goods ( $\bar{p}_{r,t}^k$ ).

<sup>8</sup>In a first step, the government calculates the expected fiscal balance without planned investment spending, which is equal to its expected income minus its expected automatic expenditures. The maximum amount that can be spent on capital goods is equal to the sum of this expected fiscal balance and the allowed fiscal deficit (i.e. 3% of nominal GDP).

<sup>9</sup>Whereas in a situation in which both counterparts have their deposit at the same bank, it corresponds to a simple internal operation in which it debits one deposit and credits that amount to the other deposit.

The demand for central bank reserves is thus given by

$$R_{b,r,t}^D = R_{b,r,t}^{min} - R_{b,r,t}^{claims} + R_{b,r,t}^{obl} + B_{b,r,t}^D + debtpay_{b,r,t}^e - R_{b,r,t} \quad (23)$$

where  $R_{b,r,t}^{min}$ ,  $R_{b,r,t}^{claims}$ ,  $R_{b,r,t}^{obl}$ ,  $B_{b,r,t}^D$ ,  $debtpay_{b,r,t}^e$  and  $R_{b,r,t}$  denote the minimum reserve requirement set by the central bank, reserve claims against other banks, reserve obligations against other banks and the government<sup>10</sup>, planned bond purchases, upcoming debt payments and the current stock of reserves. Minimum reserve requirement corresponds to a share  $res$  of total deposits.

Banks with excess reserves ( $R_{b,r,t}^D < 0$ ) offer them at the interbank market. Banks with excess demand ( $R_{b,r,t}^D > 0$ ) go through these offers and sort these by attractiveness. In case that the first offer is not enough to satisfy the bank's entire demand for reserves, it will take the remaining amount from the next on the list. It proceeds until its entire demand is satisfied or the market becomes empty. In this case it will acquire the missing amount from the central bank. Interbank and central bank loans have to be repaid after  $\xi_b = 1$  period. Furthermore it has to be noted that since we assume that the interest on the interbank market is entirely determined by the CB rate, which means that all banks offer the same interest rate, this comes down to banks taking the offer from the bank located closest to them.

Gross bank profits  $R_{b,r,t}^{gross}$  result from the difference between received interest income (interest on provided loans to households, firms and banks, interest on its CB deposit and interest income from government bonds) and interest expenditure (interest on interbank loans, central bank loans and client deposits).

$$R_{b,r,t}^{gross} = inc_{b,r,t}^i - expenditure_{b,r,t}^i \quad (24)$$

Bank profit is subject to the corporate tax rate  $\tau^c$ , which means that net profits are equal to

$$R_{b,r,t}^{net} = R_{b,r,t}^{gross} - \tau^c \cdot R_{b,r,t}^{gross} \quad (25)$$

When profits are distributed to the owner, they become subject to the income tax  $\tau^r$ , which is withheld by the bank to be transferred to the government account. In line with the Basel framework we assume that banking regulation requires banks to have a leverage ratio  $l_{b,r,t} = D_{b,r,t}^{re} / \Sigma A_{b,r,t}^L$  not lower than 3%, where  $D_{b,r,t}^{re}$  denotes the bank's retained earnings deposit and  $\Sigma A_{b,r,t}^L$  the sum of loan assets (loans to households and firms, interbank loans and government bonds). We assume that whenever bank leverage is in line with the minimum leverage ratio set by banking regulation, banks distribute all profits. Whenever a bank's leverage ratio falls below that requirement, it becomes restricted in its ability to distribute profits and is only allowed to distribute a certain share  $\tau_b$ . Distributed bank profits  $R_{b,r,t}$  thus are equal to

$$R_{b,r,t} = R_{b,r,t}^{net} - \tau^r \cdot R_{b,r,t}^{net} \quad (26)$$

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<sup>10</sup>Reserve flows arising from tax payments to the government are also settled at the end of the period.



in the first case, whereas in the latter case it becomes

$$R_{b,r,t} = \tau_b \cdot R_{b,r,t}^{net} - \tau^r \cdot R_{b,r,t}^{net} \quad (27)$$

Banks pay interest  $i_D$  on positive deposits and charge interest  $i_{L,b,r,t}$ , which is currently offered rate on loans, on negative deposits. While the interest rate on deposits is assumed exogenous, the interest rate on loans is set as a mark-up  $m_{b,r,t}$  on the central bank interest rate (since it is assumed to be equal to the interbank interest rate). Bank loans are repaid in equal installments over the course of  $\xi_{h,f}$  periods. We assume that banks increase their mark-up by  $\rho_b$  when their stock of loan assets  $\Sigma A_{b,r,t}^L$  is above their target  $A_{b,r,t}^T$  and reduce their mark-up by that same factor when it is below that target. Assuming that banks want to exploit the minimum leverage ratio set by regulation (0.03), this target becomes

$$A_{b,r,t}^T = \frac{D_{b,r,t}^{re}}{0.03} \quad (28)$$

Non-insolvent agents can overdraw their bank account. At the end of the period those agents try to balance their account by applying for a bank loan. When households and firms apply for a loan, banks assess how much additional credit they can afford. In order to do so, banks calculate how much income the agent  $a$  has potentially available for debt payments by taking its total income ( $INC_{a,r,t}$ ) and subtracting prospective debt payments  $debtpay_{a,r,t+1}^e$  (which are all debt payments currently due in the next period). Furthermore, they subtract a margin of safety  $\theta$  (see Minsky, 1986). In the case of households, this margin of safety is set with respect to the poverty line ( $\theta_{h,r,t} = \gamma_h \cdot POV_{r,t}$ ), whereas in the case of firms it is set relative to the firm's current labor cost ( $\theta_{f,r,t} = \gamma_f \cdot labor_{f,r,t}$ ). Hence, the maximum annuity payment that the bank thinks the agent can afford is

$$annuity_{a,r,t}^{max} = INC_{a,r,t} - debtpay_{a,r,t+1}^e - \theta_{a,r,t} \quad (29)$$

Calculating the loan sum that would result in that particular annuity payment yields the maximum amount of credit  $L_{a,r,t}^{max}$  offered to that agent:

$$L_{a,r,t}^{max} = annuity_{a,r,t}^{max} \cdot \frac{1 + i_{L,b,r,t}^{T_L} - 1}{1 + i_{L,b,r,t}^{T_L} \cdot i_{L,b,r,t}} \quad (30)$$

where  $T_L$  denotes the loan term. According to Minsky (1986), banks' margins of safety change over time. Particularly, banks tend to gradually relax these margins of safety in times of perceived stability. However, once things start to get worse, banks are quick to raise their margins, potentially leading to a contraction of credit supply. In terms of the model, we assume a downward tendency in the margin of safety (represented by  $\zeta_1$ ) that is counteracted by upward spikes whenever a bank experiences insolvencies of its clients (represented by  $\zeta_2$ ). The magnitude of these sudden upward corrections depends on the size of new insolvency declarations by within group  $j$  experienced by a particular bank ( $insolv_{b,r,t-1}^j$ ) relative to the bank's entire volume of

of outstanding credit within this segment ( $\Sigma L_{b,r,t-1}^j$ ) in the previous period.<sup>11</sup>

$$\gamma_{b,r,t}^j = (1 - \zeta_1) \cdot \gamma_{b,r,t-1}^j + \zeta_2 \cdot \frac{insolv_{b,r,t-1}^j}{\Sigma L_{b,r,t-1}^j} \quad (31)$$

Banks require their clients to balance their deposit within  $n_{balance}$  periods. If agents fail to balance their account within that time by either accumulating a sufficient surplus of financial funds or securing a loan, the bank will declare that agent insolvent. Once declared insolvent, the remaining negative amount on its deposit is converted into a loan and the agent can no longer overdraw its deposit. Furthermore it does not regain access to credit until all of its debt is repaid. Insolvent households have to reduce consumption demand to the poverty level, with all remaining income going to its creditors. Thereby, outstanding loans are repaid proportionately with respect to their respective share in the agents total insolvency debt. In case of insolvent firms, banks contemplate whether to liquidate the firm. In particular, they check whether its income over the previous 12 periods has exceeded its labor cost over that same period. If that is the case, the firm is allowed to continue as banks expect to receive some of their funds back. On the other hand, if income is not above labor cost, the firm enters the process of liquidation, meaning that it has to quit its workers and stop production. Remaining inventories are sold at fire sale prices ( $p_{f,r,t}$  is reduced by rate  $\chi$  each period until all inventories have been sold). Once all inventories have been sold and all financial funds of the firm have been used for debt repayment, liquidation is finished.<sup>12</sup>

### 3.7 Central bank

The two regions share a common central bank. Banks and governments hold reserve deposits at the central bank. The central bank pays interest  $i_{D,CB}$  on these deposits and charges interest  $i_{L,CB}$  on central bank loans taken by banks. Both rates are assumed exogenous. Central bank profits are calculated similarly to profits of private banks, the only difference being that the central bank is not subject to the corporate tax ( $t_c = 0$  for the central bank). The central bank distributes all its (positive) profits equally among the governments.

## 4 Simulations

In what follows we conduct five sets of simulations, where each setup includes 25 simulation runs. After choosing the starting parameters (see the appendix), each run is given a 50 period burn-in phase not documented in the figures since the sole purpose of this phase is to allow the model to settle on a more or less stable path. Once these periods have passed, we start with the actual analysis. Generally, the order in which agents of a certain type are allowed to make decisions and enter the market is redrawn every period in order to avoid systematic advantages or disadvantages among agents.<sup>13</sup> Agents are drawn independent of their region of origin, so

<sup>11</sup>For similar mechanisms in an agent based model see Gräbner-Radkowitzsch *et al.* (2022). For an application within stock-flow consistent models see Kapeller & Schütz (2014), Kapeller *et al.* (2018) and Gräbner *et al.* (2022).

<sup>12</sup>In case that remaining funds exceed the amount of debt owed to banks, the residual part gets distributed to the owner.

<sup>13</sup>A household would e.g. have an advantage if it could always enter the market for consumption goods first, since it could always pick the most attractive products. Similar would be true for firms and governments entering

that e.g. once it is the households turn to make consumption decisions, households from North and South are drawn from the same pool until all households have made that decision. The same counts for firms, banks and the two governments. Each figure reports the average of these 25 runs as well as the extreme values observed or each period (i.e. minimum and maximum values observed across runs) in order to give an idea of the degree of variation across runs and the possibility of extreme developments taking place.

In the first setup, representing the baseline scenario against which the other scenarios will be compared against, regions North and South are assumed completely identical to each other. Any deviations between the regions are therefore down to random variations in the order in which agents are allowed to take action. The next three scenarios try to capture in a very stylized way some key features that happened in the run-up to the Great Recession: The first of these scenarios assumes an investment boom solely taken place in the South, the second an increase of competitiveness in the North and the third one an increase in nominal wage growth in the South. Finally, the last scenario takes all of the previous three scenarios together.

#### 4.1 Baseline simulations

In the baseline scenario the regions North and South are completely identical to each other. Differences in outcomes are therefore only down to random deviations in the order in which agents are allowed to take action. Figure 2 displays the evolution of aggregate purchases of goods by households, firms and governments in regions North and South. First of all it shows that averages are quite stable across the observation period and roughly similar across the two regions. However, they also reveal considerable outliers and at times quite sudden movements. Especially interesting is the observation that the minimum observation of aggregate spending in the North falls considerably below the average, coinciding with very low government spending. This seems to indicate that though these economies seem to do well most of the times, the assumed fiscal rule (requiring governments to try to keep their deficits below 3% of GDP) in combination with the government spending regime assumed in equation 21 seem insufficient to balance the economy when events turn very unfavorable.<sup>14</sup>

While the previous figure showed the (realised) demand for goods, figure 3 illustrates aggregate production according to sectors. Here aggregate production in the North shows a slight downward trend, which again seems to be driven by the minimum observation described before. There should not be any systematical difference, since the maximum values observed in North and South are pretty similar to each other, with both hitting full employment at the best of times (see figure 6a).

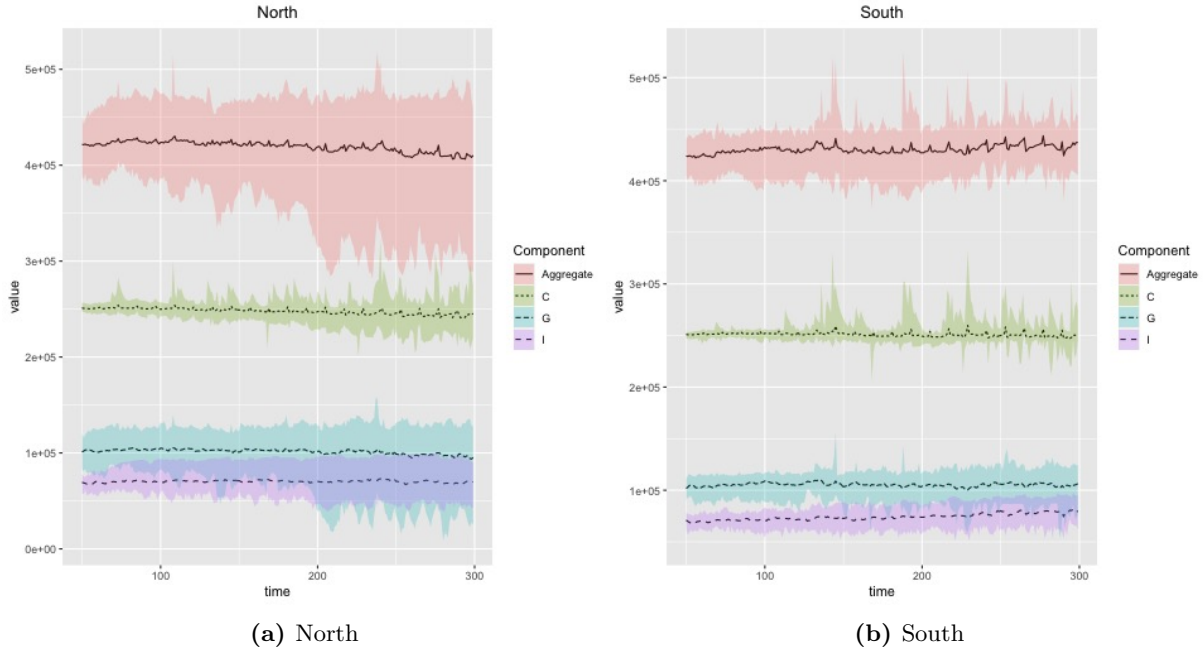
Overall, the reason for the diverging averages is a slight upward trend in Southern exports (mirrored by the downward trend in Northern imports), although again that should not be a systematic issue since both averages are well in between the respective minimum and maximum values observed in the other region. Moreover, although the average trade balance as a percentage of GDP (figure 5b) trends away from zero, the zero line is well in between the minimum and

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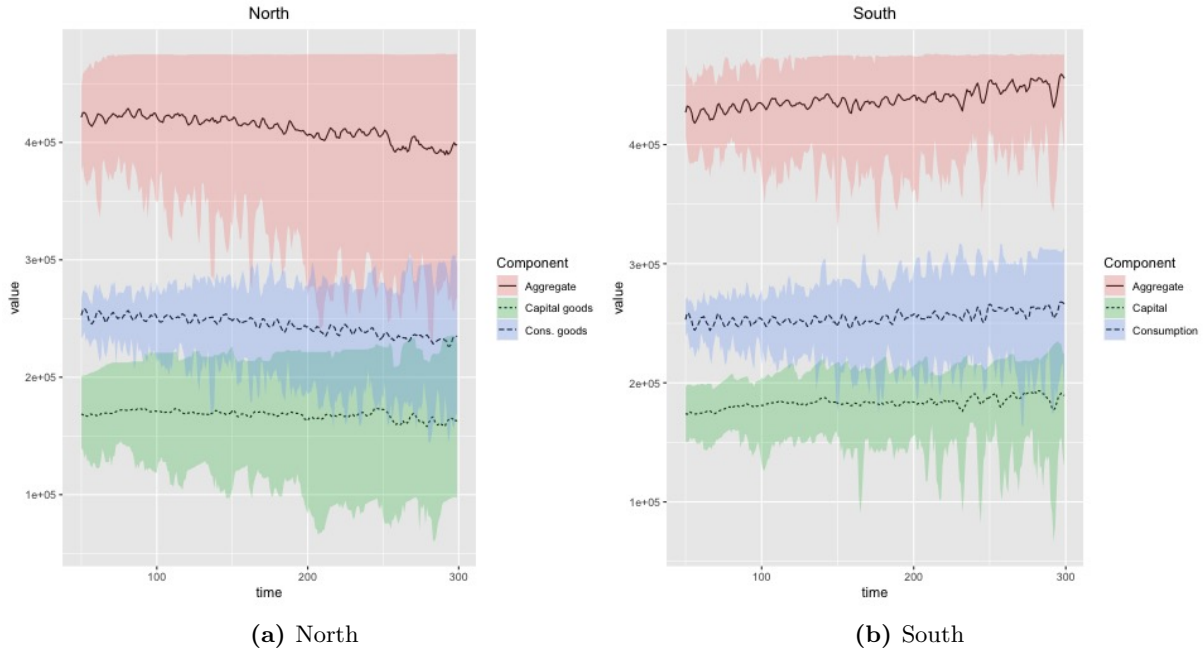
the market for capital goods or firms entering the labor market.

<sup>14</sup>Dropping the fiscal rule reduces the maximum observed unemployment rate in the North significantly, though some difference compared to the South still remains. See section B of the appendix.

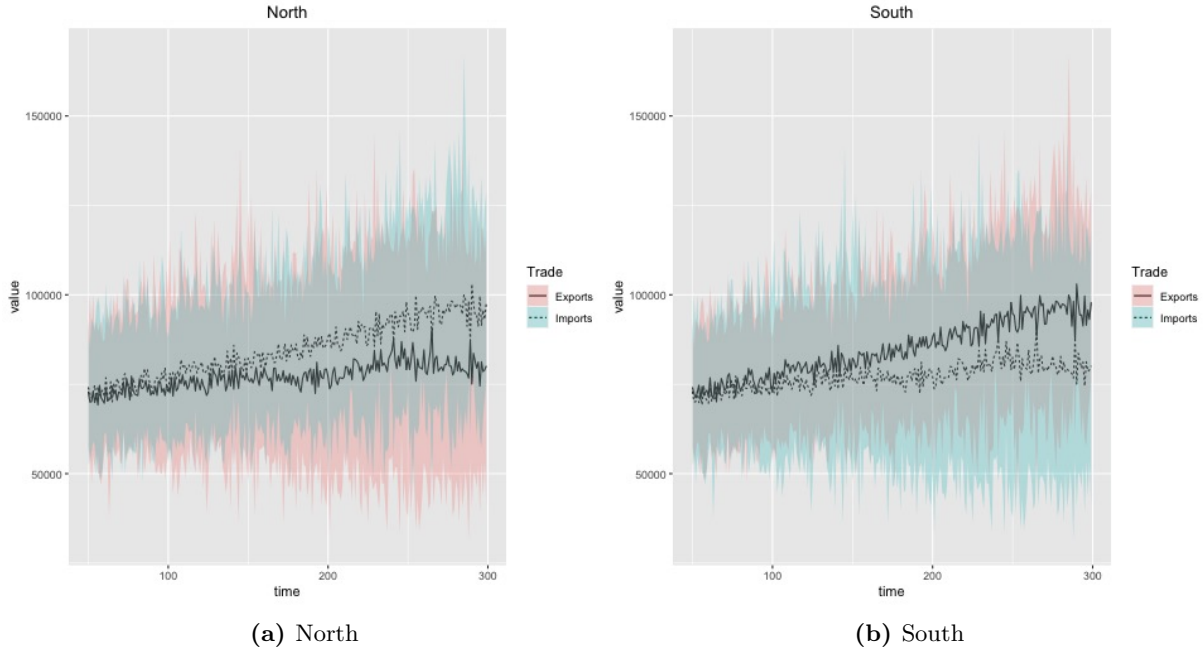
**Figure 2:** Aggregate purchases of goods by households (C), firms (I) and governments (G) (mean of 25 runs; shaded area: min. and max. observation)



**Figure 3:** Aggregate production in the consumption and capital goods sector (mean of 25 runs; shaded area: min. and max. observation)



**Figure 4:** Exports and imports (mean of 25 runs; shaded area: min. and max. observation)



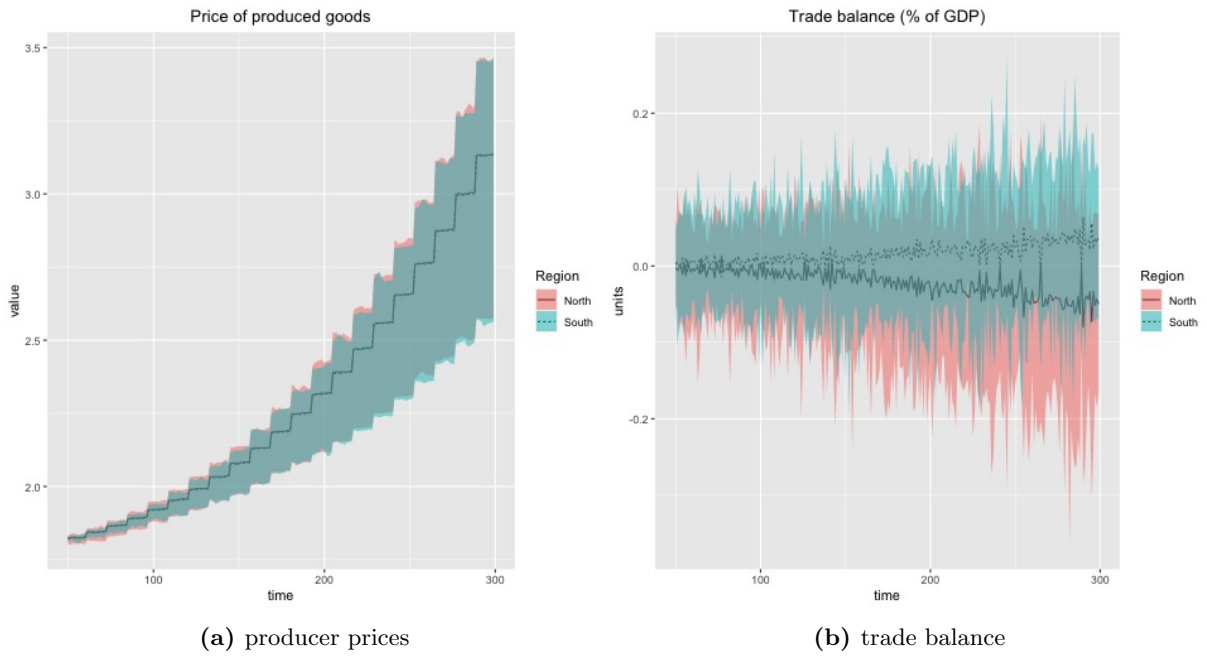
maximum observations. Average producer prices do not differ much between regions and follow a stepwise upward path driven by wage negotiations happening every 12 periods (figure 5a).

Average unemployment rates are around 10%, with the rate trending upwards in the North and downward in the South. Again the upward trend in the North is driven by the maximum observations, which are well above 30% (while minimum observations hardly depart from 0% for the same time period). The real wage rate (measured relative to the price index of purchased consumption goods in that region) is trending slightly downwards in both regions (something that will change in section 4.4).

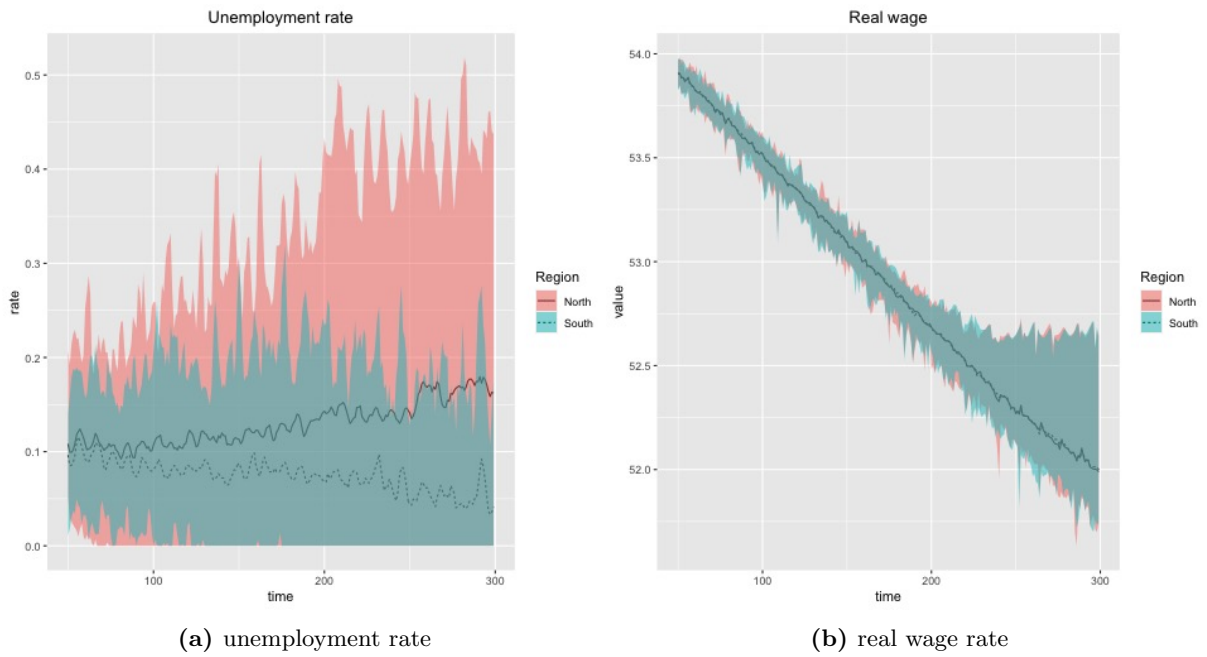
Figure 7 shows that average financial aggregates as % of GDP are quite stable, except for two extreme but very short-lived periods of very high maximum observations in household debt in the North (leading to corresponding surges in household deposits as debt creates deposits). Average insolvency rates of households and firms, as well as the rate of liquidated firms are also comparable in North and South, with an upward trend in average liquidated firms observed in both regions, meaning that the population of active firms is slightly decreasing over time. The average rate of insolvent households remains close to zero and only rises slightly in the North towards the end of the simulation period. This, however, also seems to be driven by the extremely high maximum value (above 30%) observed in one of the simulation runs.

Banks average margins of safety applied to firms and households are on average slowly declining in both regions, though both regions see margins for firms rise above initial values in at least one simulation run.

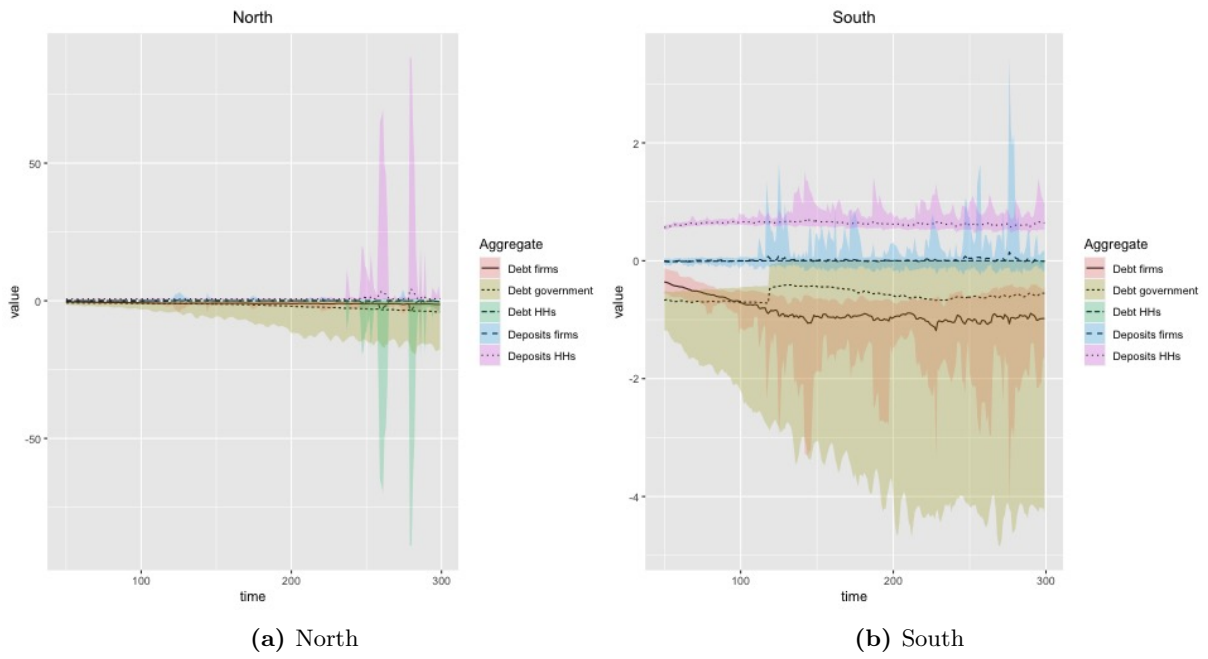
**Figure 5:** Prices and trade balance (mean of 25 runs; shaded area: min. and max. observation)



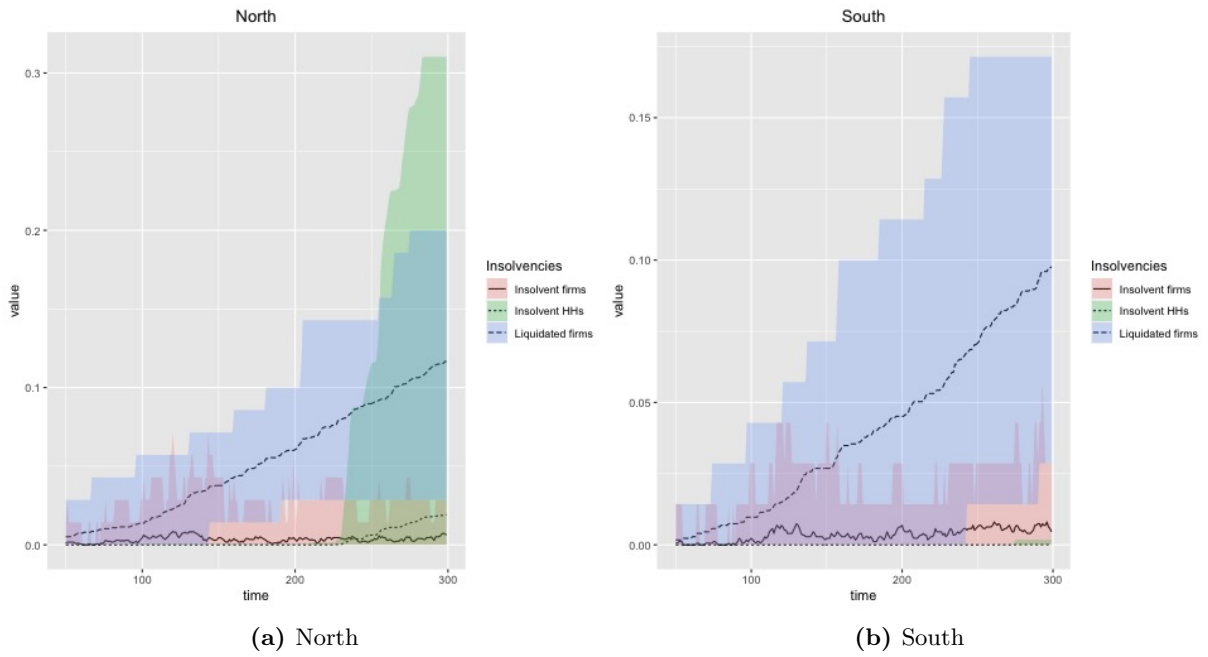
**Figure 6:** Unemployment and real wage (mean of 25 runs; shaded area: min. and max. observation)



**Figure 7:** Financial aggregates of non-financial institutions in % of GDP (mean of 25 runs; shaded area: min. and max. observation)

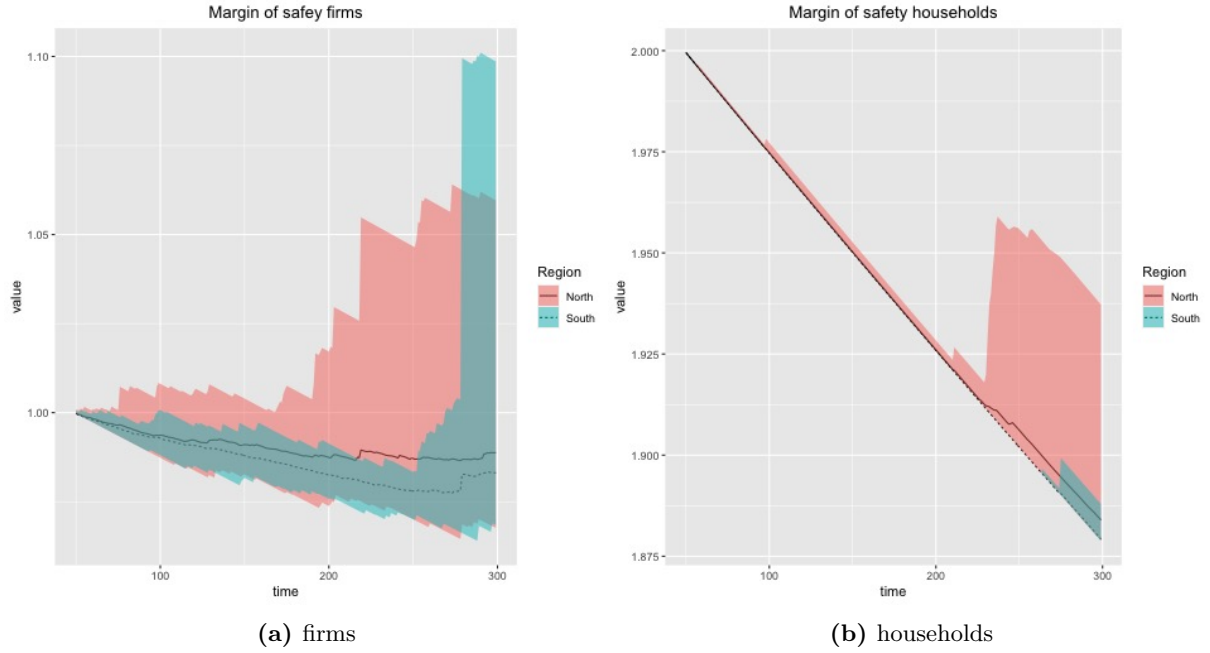


**Figure 8:** Insolvency statistics in % (mean of 25 runs; shaded area: min. and max. observation)





**Figure 9:** Average banks' margins of safety (mean of 25 runs; shaded area: min. and max. observation)



## 4.2 Investment boom

The next scenario looks at an investment boom that takes place only in the South. Particularly, it assumes that once the burn-in period is over, the desired rate of capital stock growth in the South is permanently raised by a factor  $\delta_g$ , turning equation 11 into

$$g_{f,s,t}^D = \gamma_1 \cdot \frac{u_{f,s,t-1} - \bar{u}}{\bar{u}} + \gamma_2 \cdot \frac{r_{f,s,t-1} - \bar{r}}{\bar{r}} + \delta + \delta_g \quad (32)$$

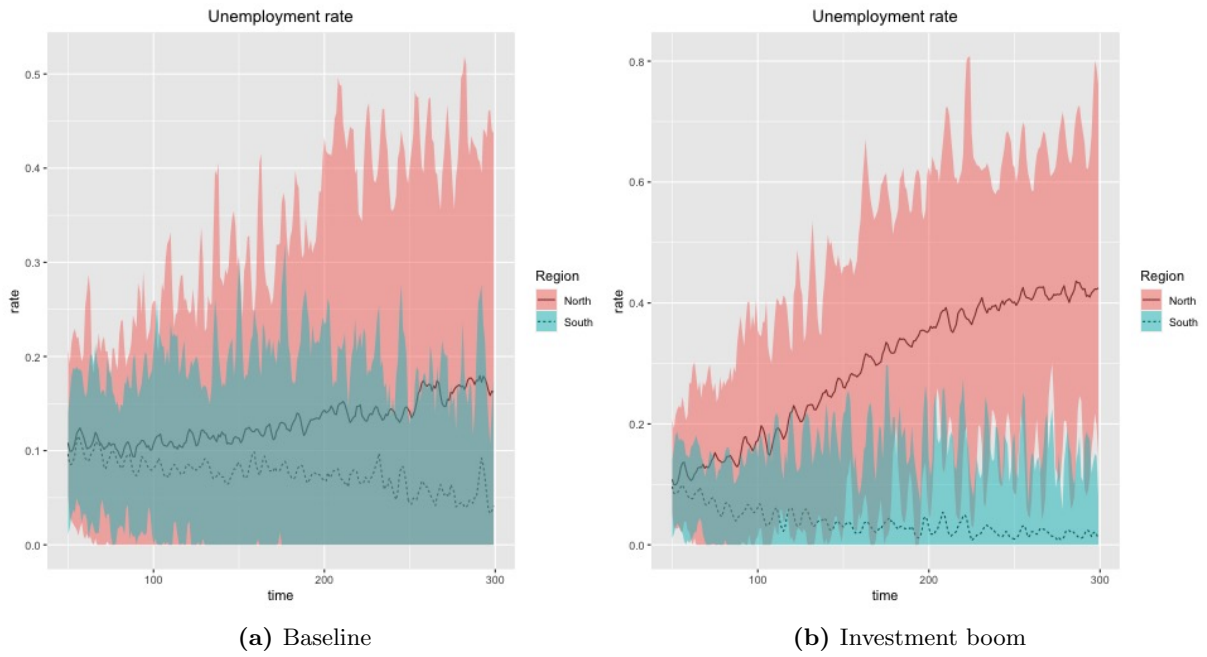
for the Southern case.

Unsurprisingly, unemployment in the South declines as a result. However, a bit more surprising is that unemployment in the North rises substantially (figure 10). The latter is probably down to the fact that since Southern firms now accumulate a larger capital stock, they become less constrained by their production capacities. This means that they are more flexible in reacting to sudden increases in demand, enabling them to capture a larger market share. Having a larger capital stock also means that workers will on average be more productive (see figure 11), since it avoids bottleneck situations in which firms have enough workers but lack the necessary capital, de facto leading to the involuntary idleness of some workers. Higher labor productivity transforms into lower prices (figure 12) and higher exports/lower imports (figure 13).

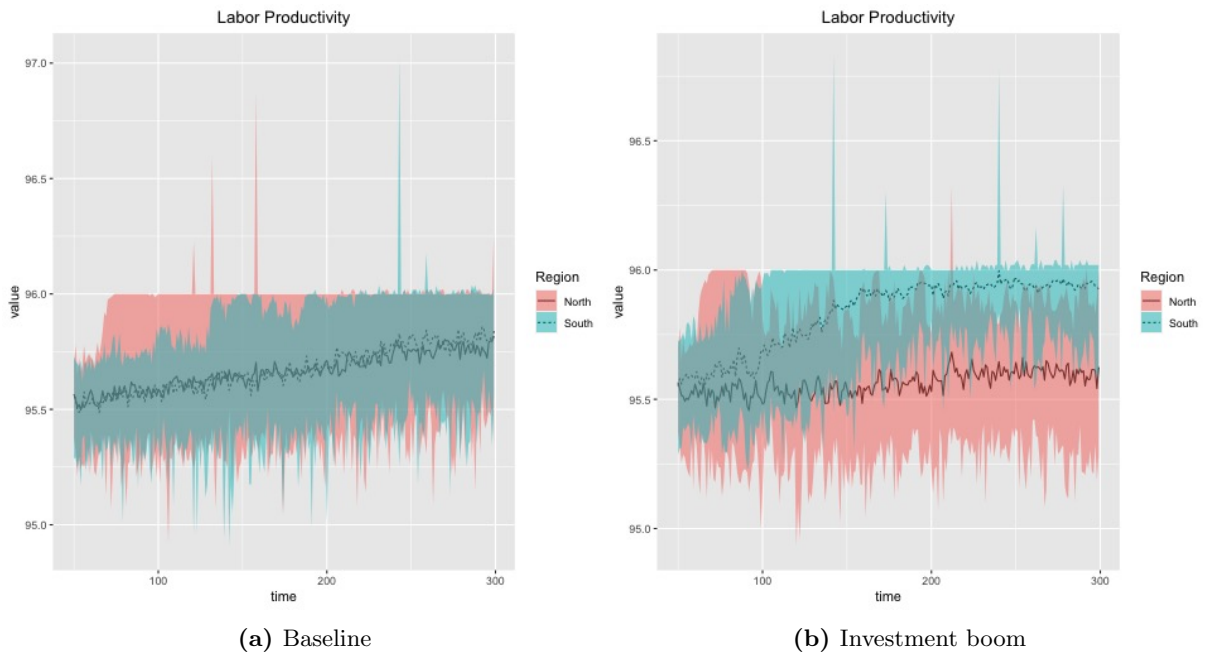
As a result, firm liquidations and household insolvencies go down in the South but rise markedly in the North (figures 14 and 15).



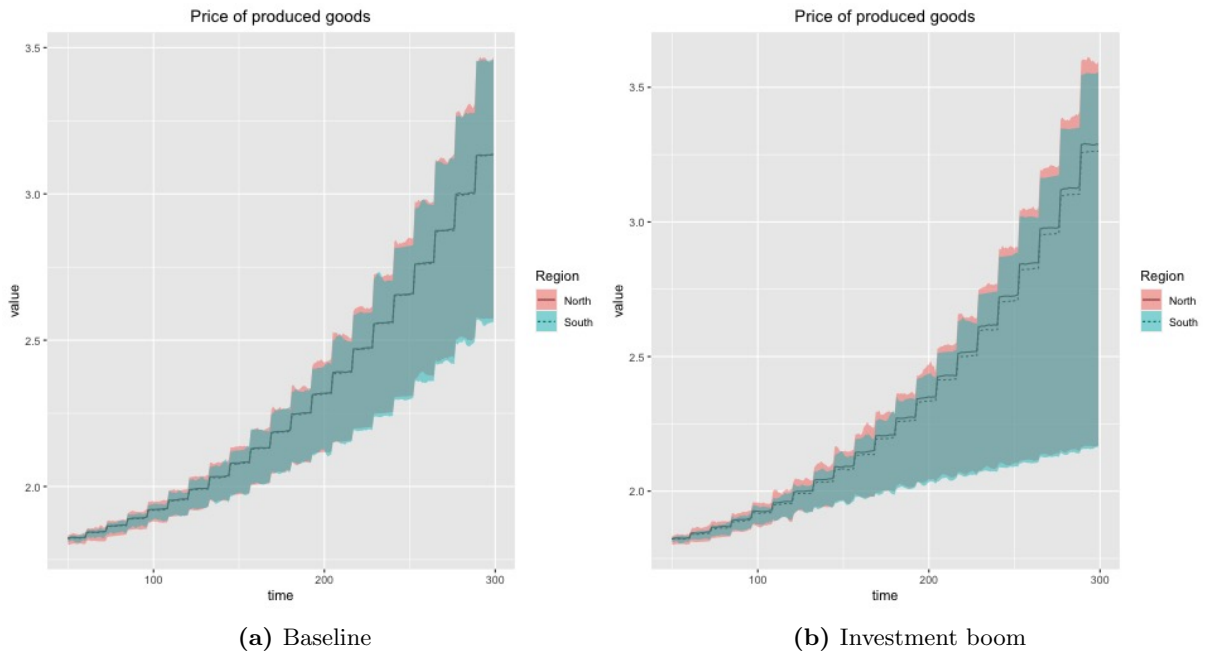
**Figure 10:** Unemployment rate (mean of 25 runs; shaded area: min. and max. observation)



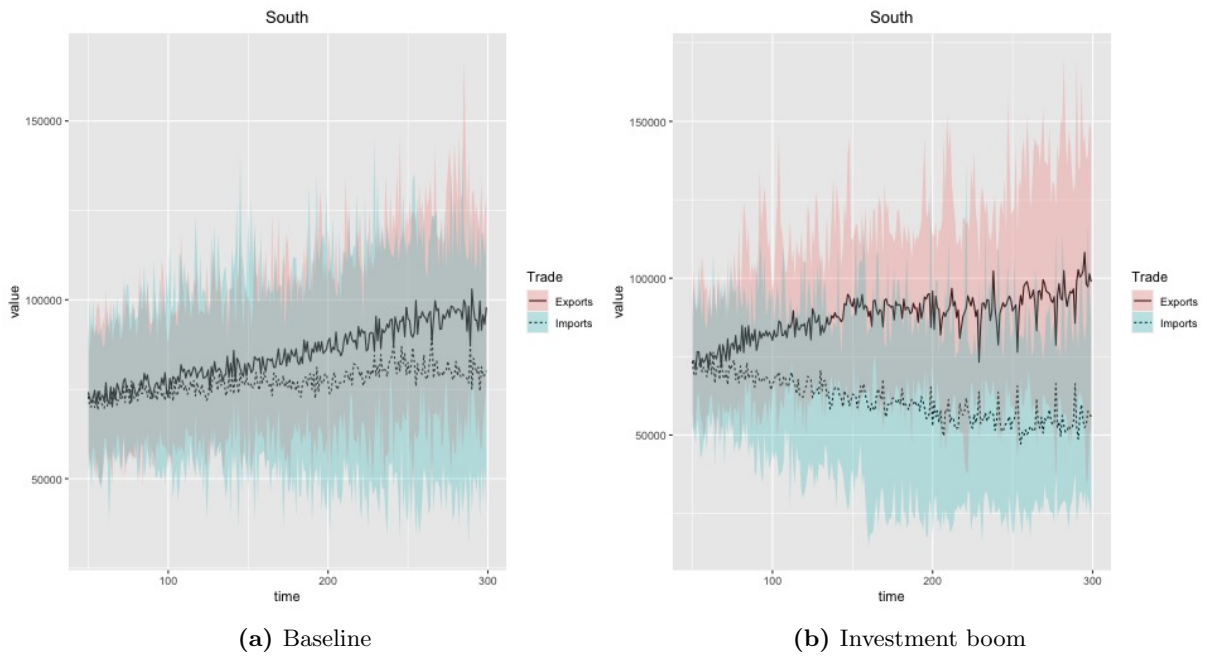
**Figure 11:** Labor productivity (mean of 25 runs; shaded area: min. and max. observation)



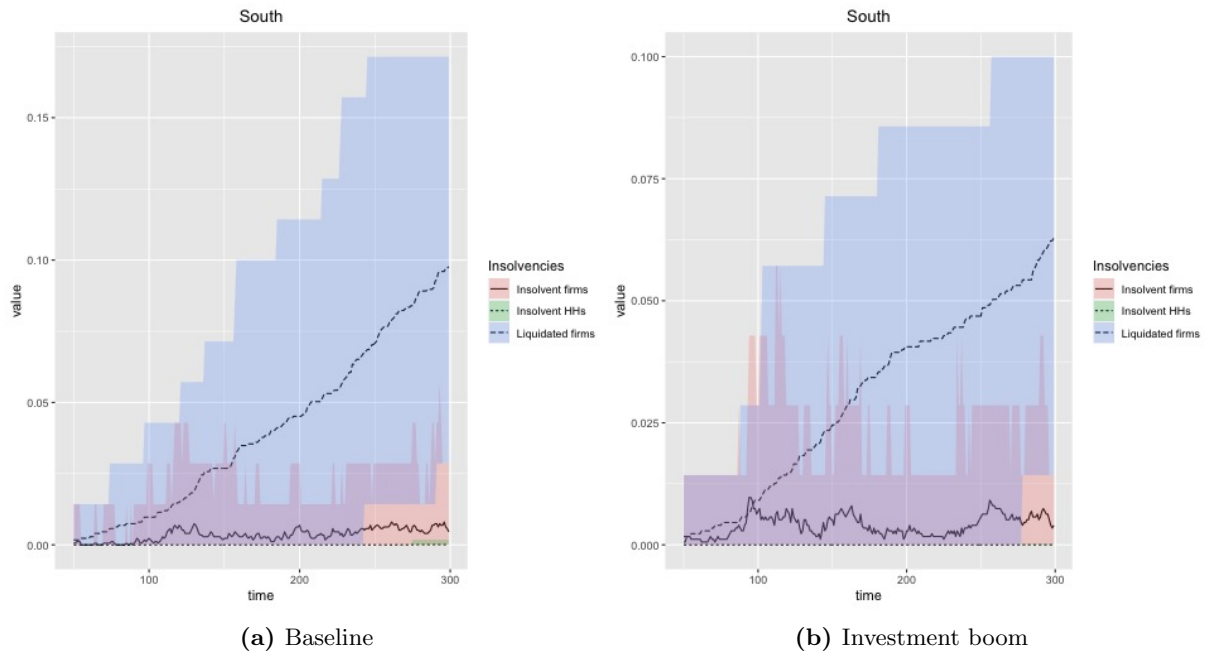
**Figure 12:** Prices (mean of 25 runs; shaded area: min. and max. observation)



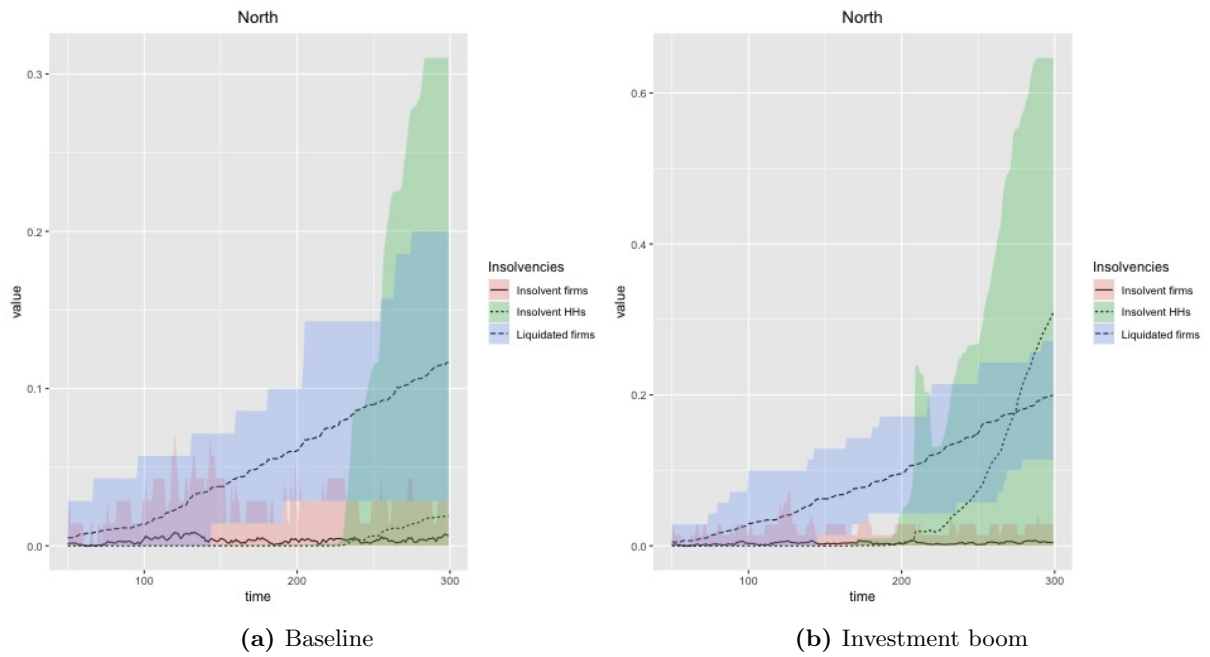
**Figure 13:** Exports and imports: South (mean of 25 runs; shaded area: min. and max. observation)



**Figure 14:** Insolvency statistics: South (mean of 25 runs; shaded area: min. and max. observation)



**Figure 15:** Insolvency statistics: North (mean of 25 runs; shaded area: min. and max. observation)

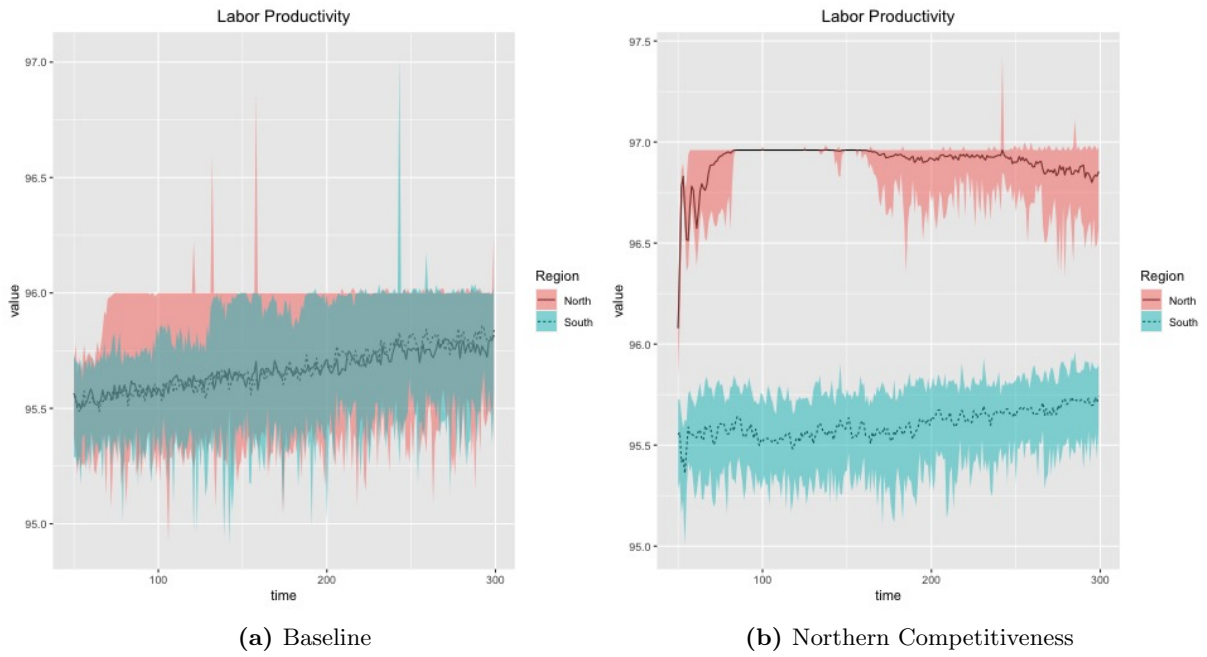


### 4.3 Northern competitiveness

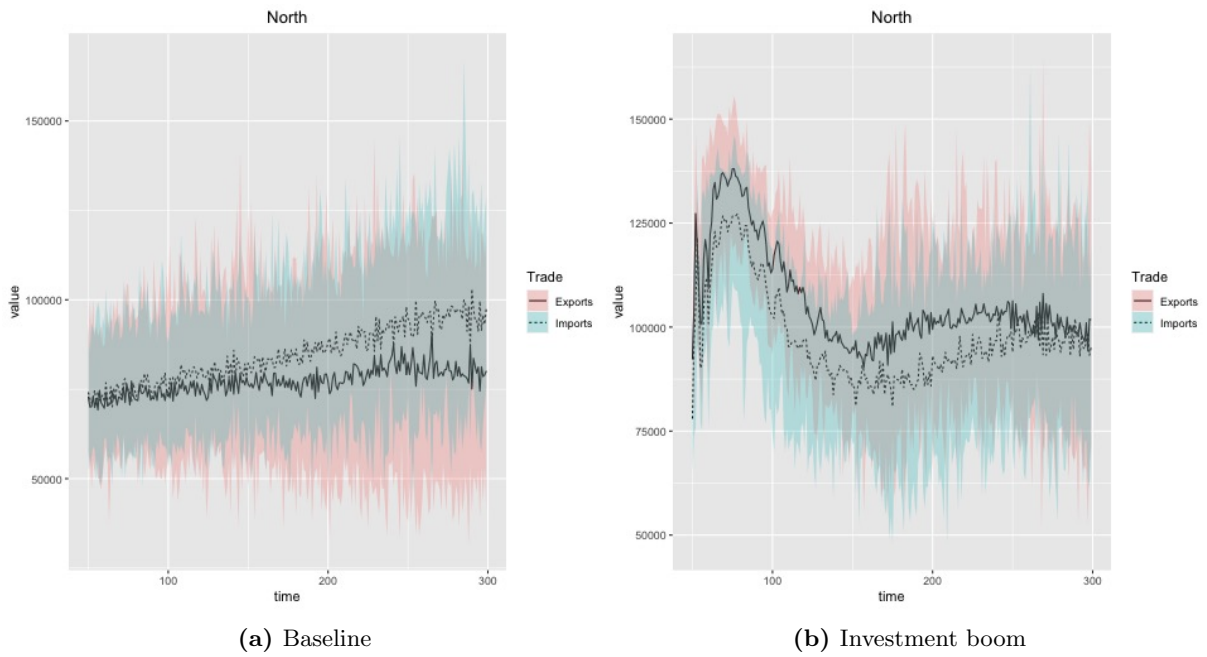
The next scenario assumes a rise in competitiveness in the North, personified by a permanent increase in the capital-labor ratio  $l_{k,r}$  by rate  $\delta_l$  once the burn-in period is over.

As labor productivity in the North goes up (figure 16), Northern exports increase. The trade balance initially turns in favor of the North (figure 19). Rising exports lead to lower unemployment and higher demand for imports (figures 17 and 18). As a result, the initial Northern trade surpluses disappear over time.

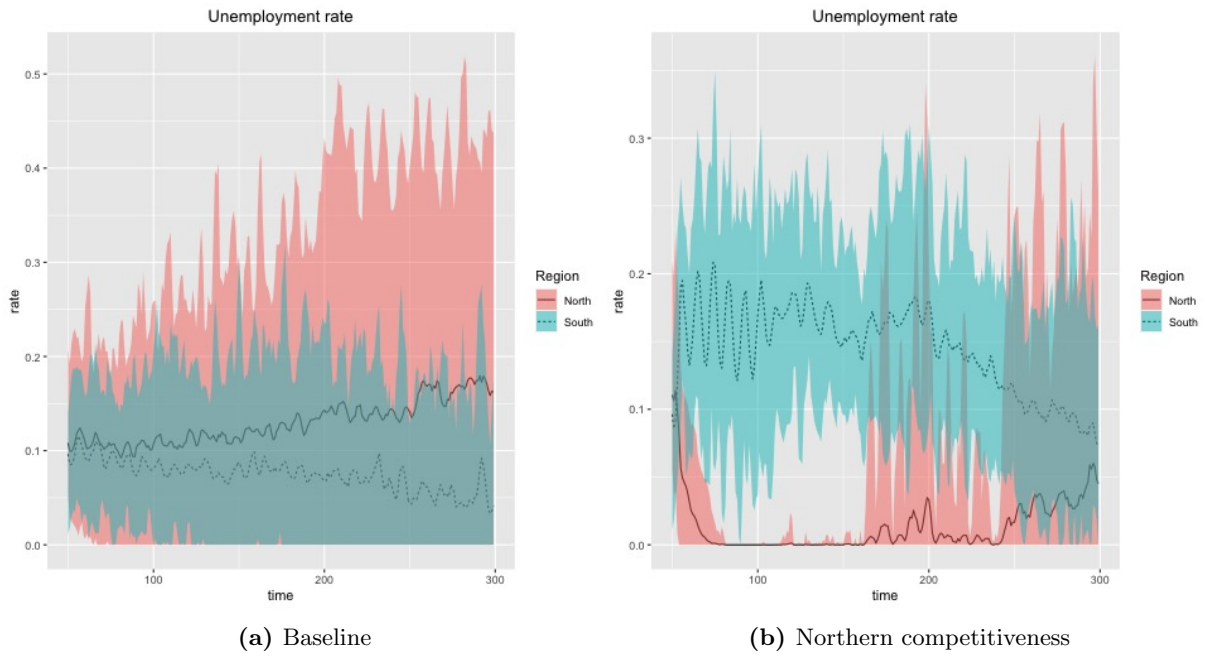
**Figure 16:** Labor productivity (mean of 25 runs; shaded area: min. and max. observation)



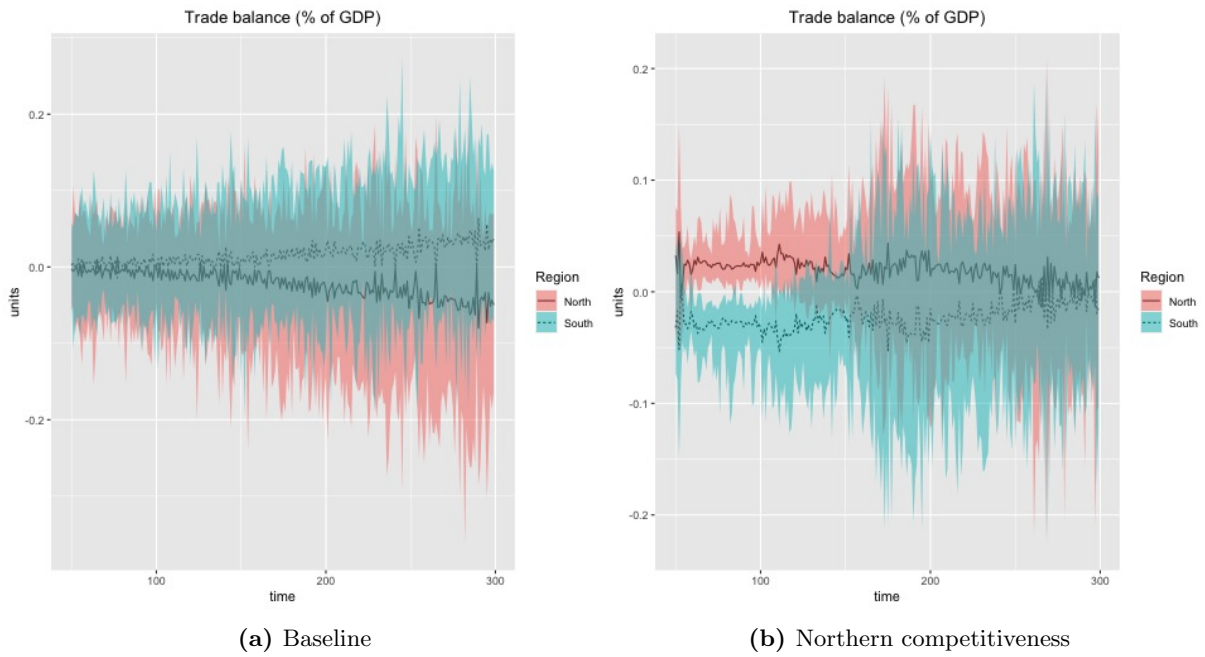
**Figure 17:** Exports and imports: North (mean of 25 runs; shaded area: min. and max. observation)



**Figure 18:** Unemployment rate (mean of 25 runs; shaded area: min. and max. observation)



**Figure 19:** Trade balance (mean of 25 runs; shaded area: min. and max. observation)



#### 4.4 Southern wage growth

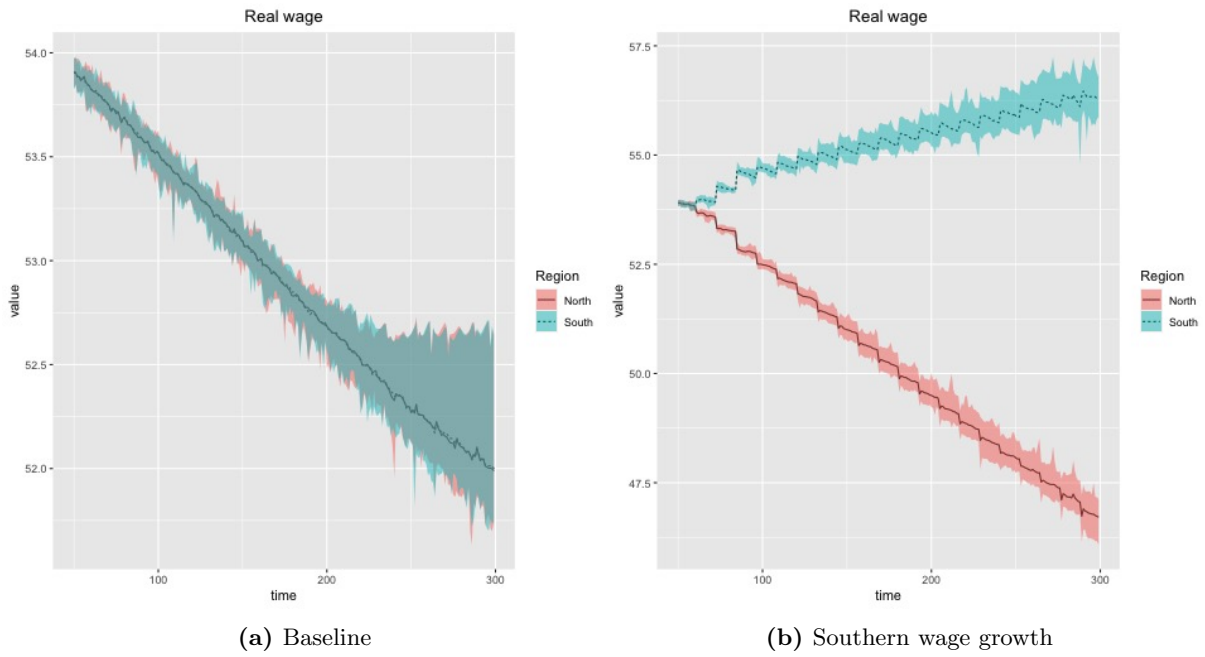
The next scenario looks at a rise in wage growth happening exclusively in the South. In particular, it assumes that bargaining power in the South increases by  $\delta_b$ , turning equation 33 into

$$b_{s,t} = b_1 \cdot (u_r^{ref} - u_{r,t-1,t-12}) + \delta_b \quad (33)$$

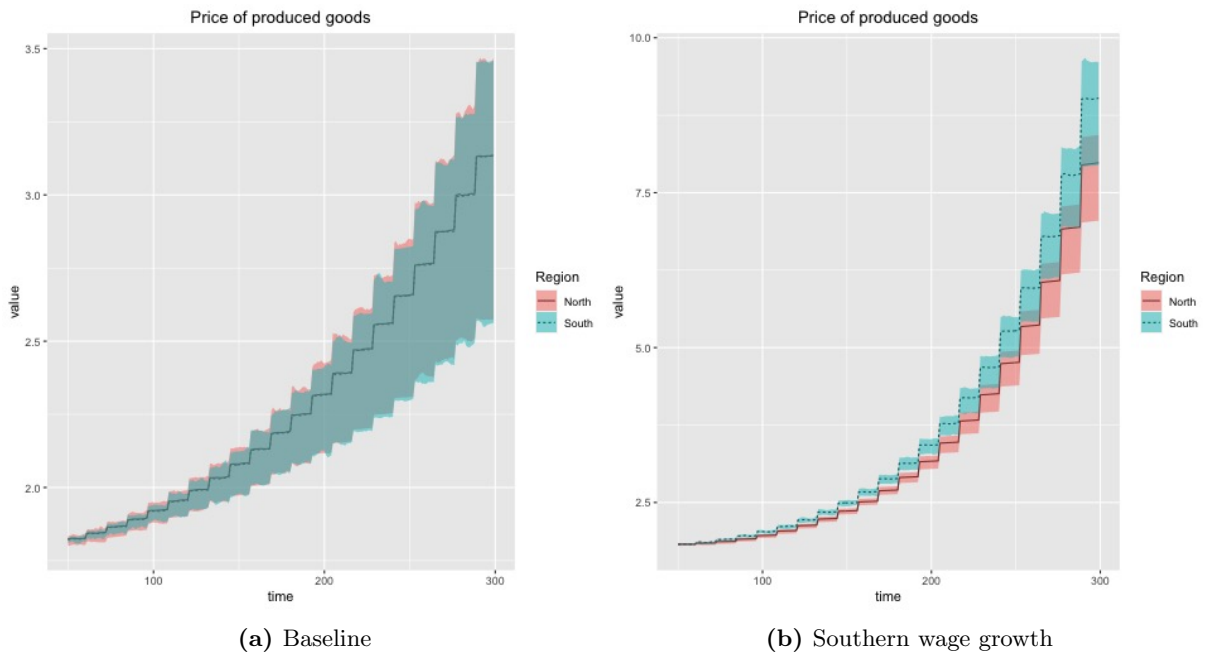
in the Southern case.

As a result of higher bargaining power, real wages in the South now follow an upward trend (figure 20). As a result, prices in the South increase (21). Rising incomes and prices increase imports from the North. Rising incomes in the North also raise Northern demand for imports, meaning that Southern exports rise too (see figure 22), with the overall trade balance swinging in favor of the North (figure 23). Unemployment goes down immediately in the North, reaching full employment rather quickly. In the South, reduced competitiveness due to higher labor costs initially leads to a rise in unemployment. However, in the medium term the additionally created unemployment disappears as rising import demand from the North raises production in the South. Hence, from the perspective of the monetary union an increase in wages leads to lower average unemployment, though the benefits are distributed in favor of the country that actually refuses to raise them.

**Figure 20:** Real wage rate (mean of 25 runs; shaded area: min. and max. observation)

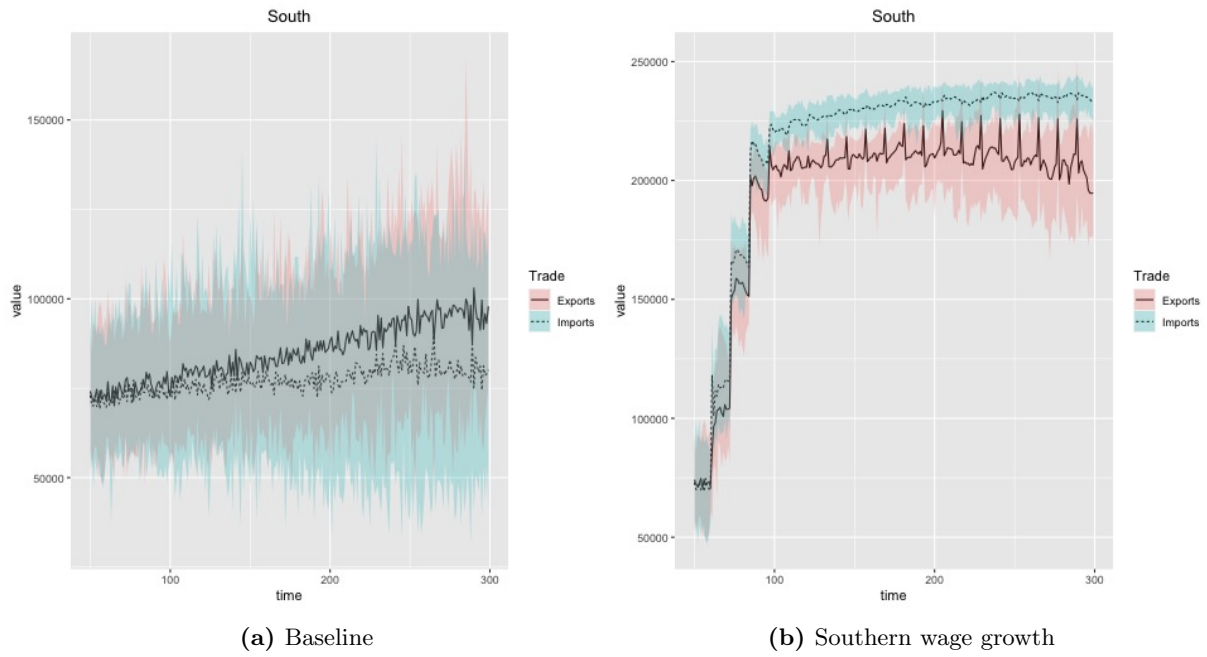


**Figure 21:** Prices of produced goods (mean of 25 runs; shaded area: min. and max. observation)

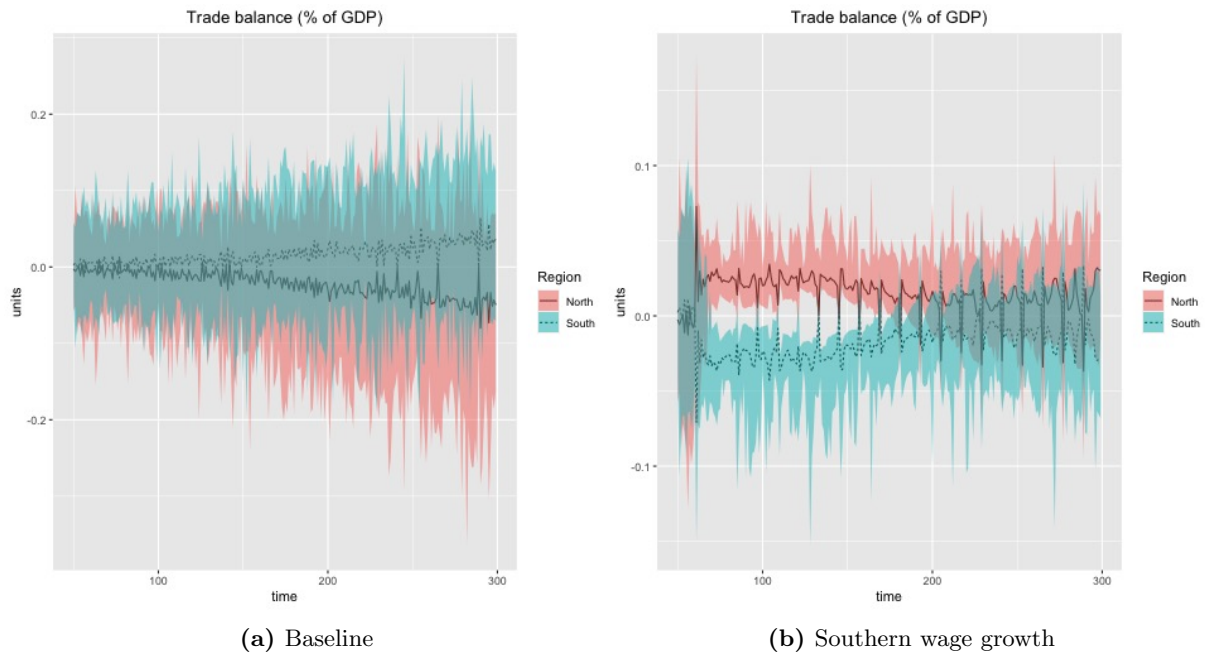




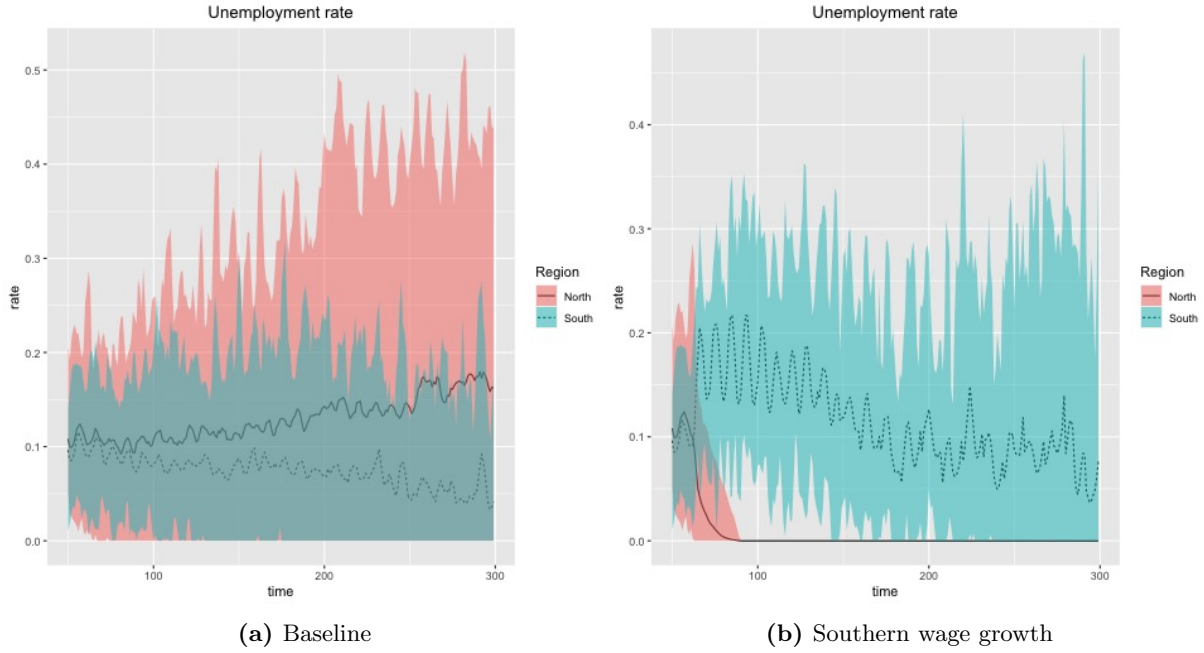
**Figure 22:** Exports and imports: South (mean of 25 runs; shaded area: min. and max. observation)



**Figure 23:** Trade balance (mean of 25 runs; shaded area: min. and max. observation)



**Figure 24:** Unemployment rate (mean of 25 runs; shaded area: min. and max. observation)



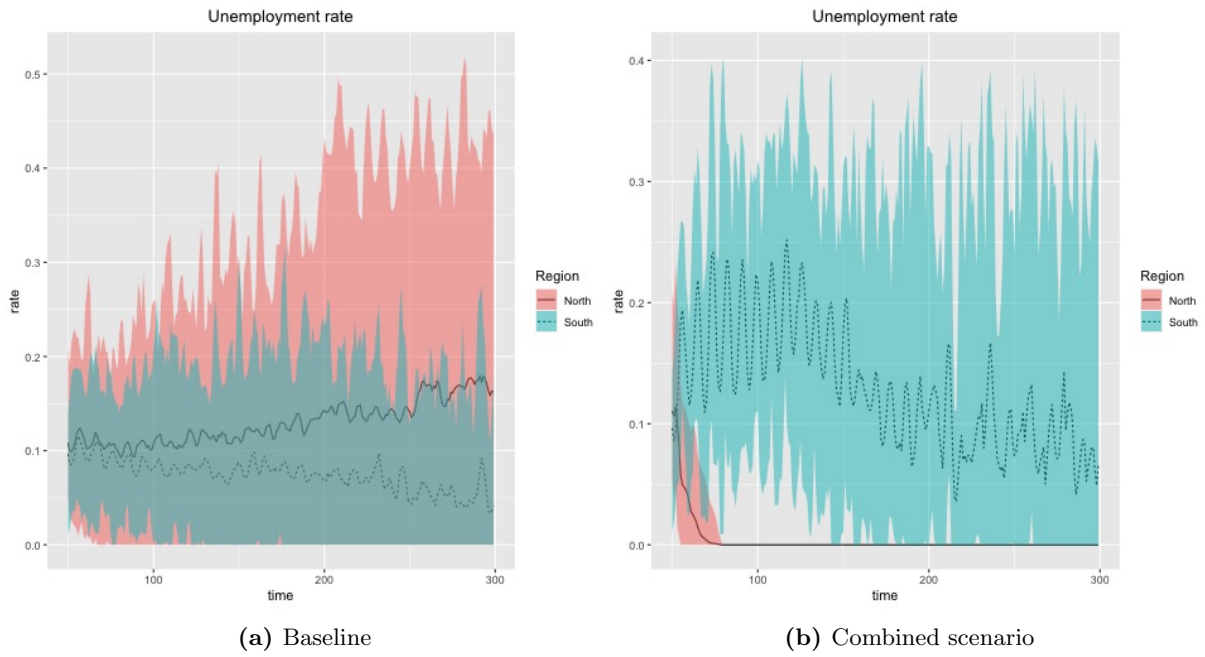
#### 4.5 The combined scenario

This section puts the previous three scenarios together in order to represent in a stylized fashion the environment that facilitated the emergence of Eurozone imbalances prior to the Great Recession. It replicates in a stylized way the low unemployment observed in the North together with the downward trend in unemployment in the South (figure 25), as well as the trade surpluses in favor of the North (figure 26). Figures 27 and 28 show the underlying trends in the real wage rate and labor productivity. Government debt in the South is initially increasing quite substantially but reverts to a declining trend later (figure 29), while indebtedness of the firm and the household sectors do not show any increasing trend. Indebtedness in the North on average moves at a low level (figure 30). Insolvencies and liquidation statistics do not deviate substantially from patterns observed in the baseline scenario (figures 31 and 32). However, while banks' margins of safety are trending downward for households, margins for firms actually tend to increase slightly in the South (figures 33 and 34).

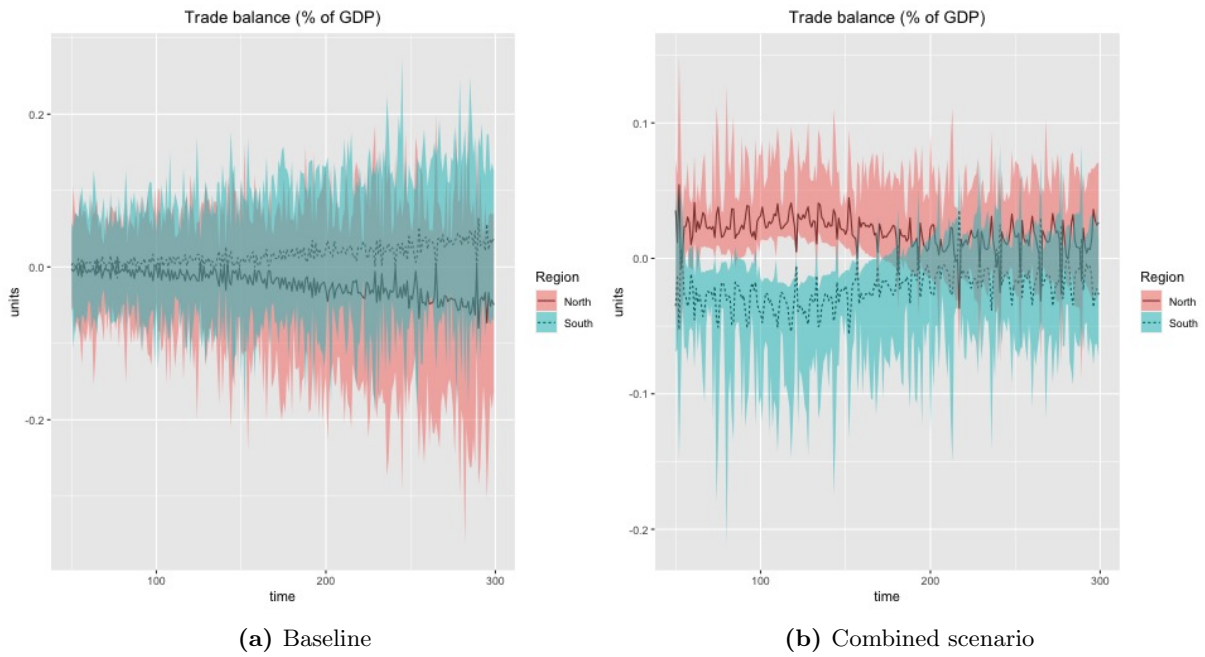
## 5 Conclusion

This paper proposes a stock-flow consistent agent-based model to replicate in a stylized way the conditions prevalent during the build-up of international imbalances in the Eurozone in the run-up to the Great Recession. Assuming an investment boom in the Southern region, an increase in productivity in the North as well as higher nominal wage growth in the South, the model is able to replicate the low unemployment rates in the North that were paralleled with falling unemployment rates in the South together with trade imbalances in favor of the North. However, despite implementing a banking sector that bears some Minskyan elements, these dynamics do not lead to the emergence of economic crises. Rather, debt dynamics do not

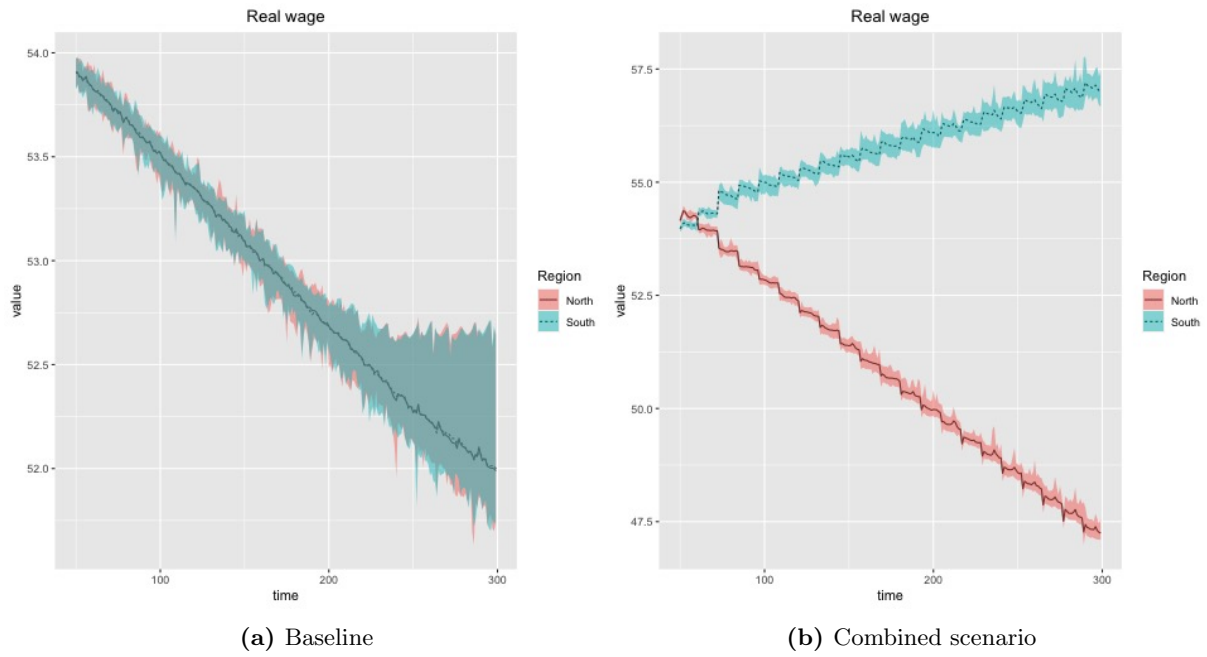
**Figure 25:** Unemployment rate (mean of 25 runs; shaded area: min. and max. observation)



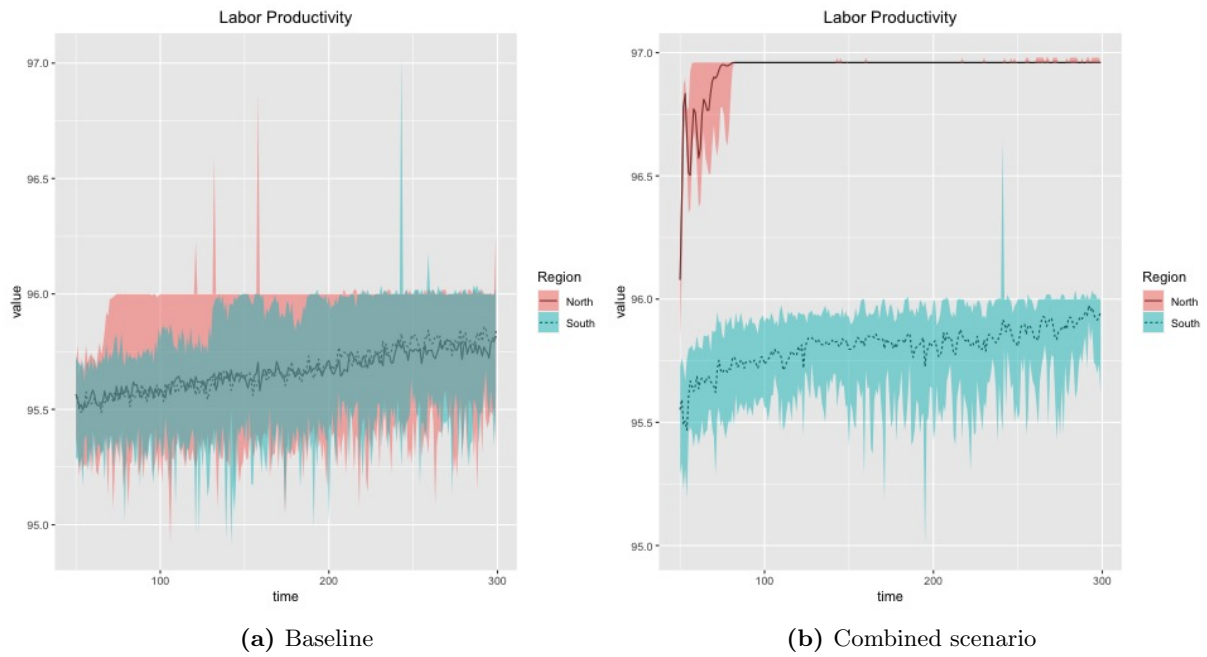
**Figure 26:** Trade balance (mean of 25 runs; shaded area: min. and max. observation)



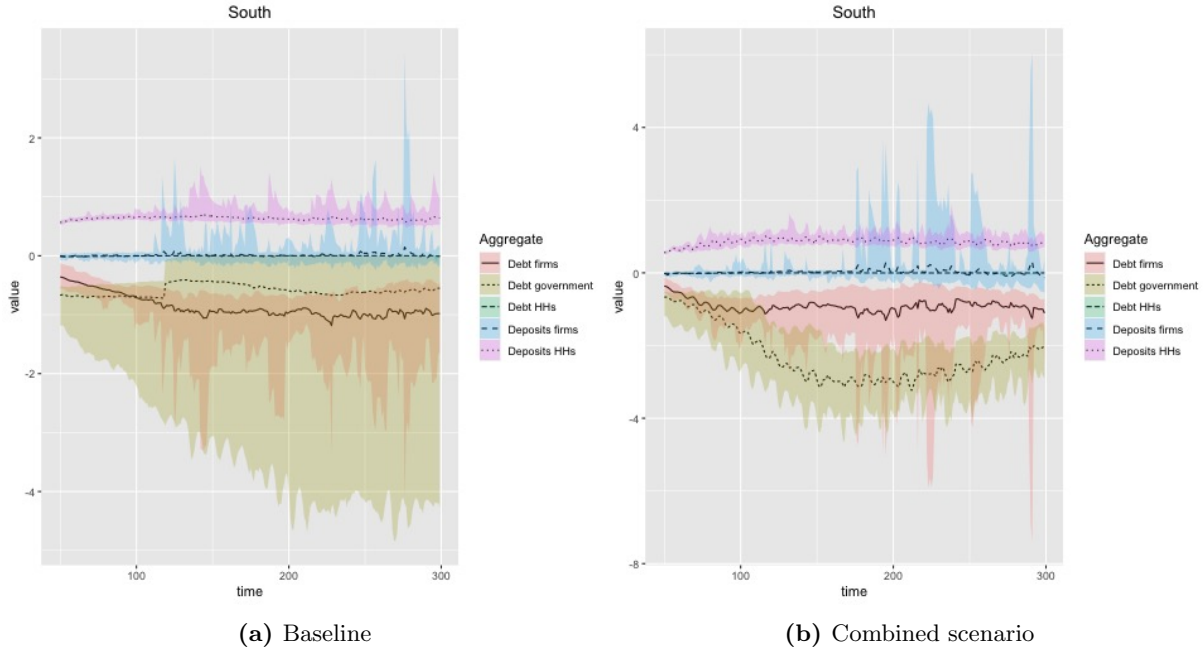
**Figure 27:** Real wage rate (mean of 25 runs; shaded area: min. and max. observation)



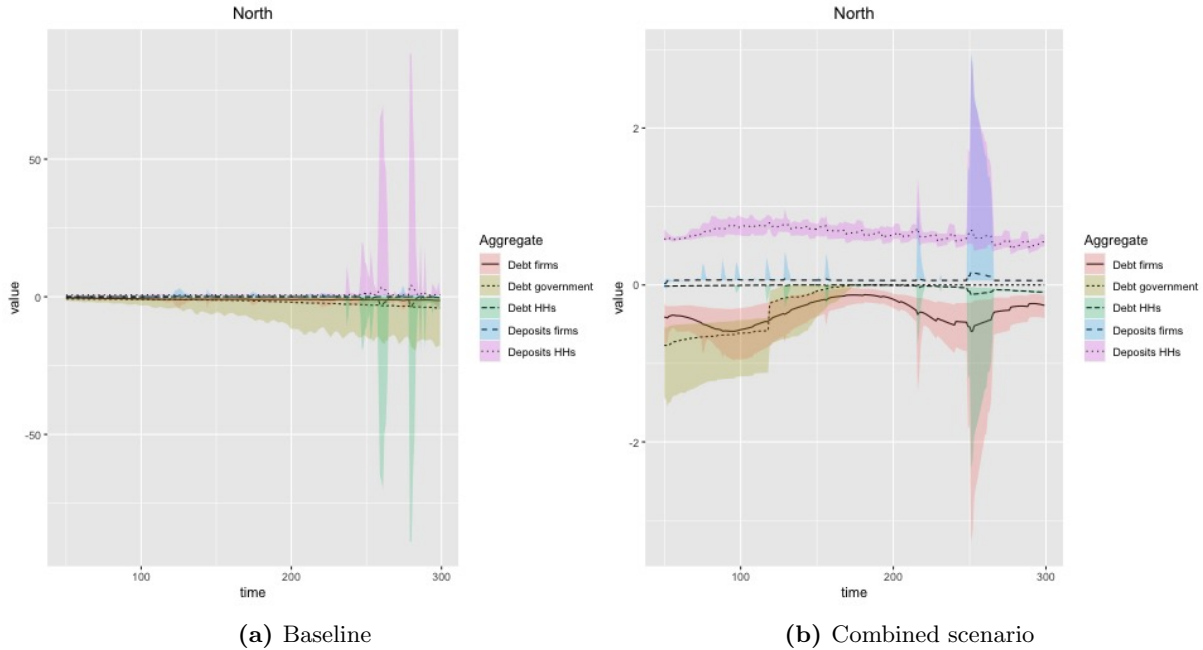
**Figure 28:** Labor productivity (mean of 25 runs; shaded area: min. and max. observation)



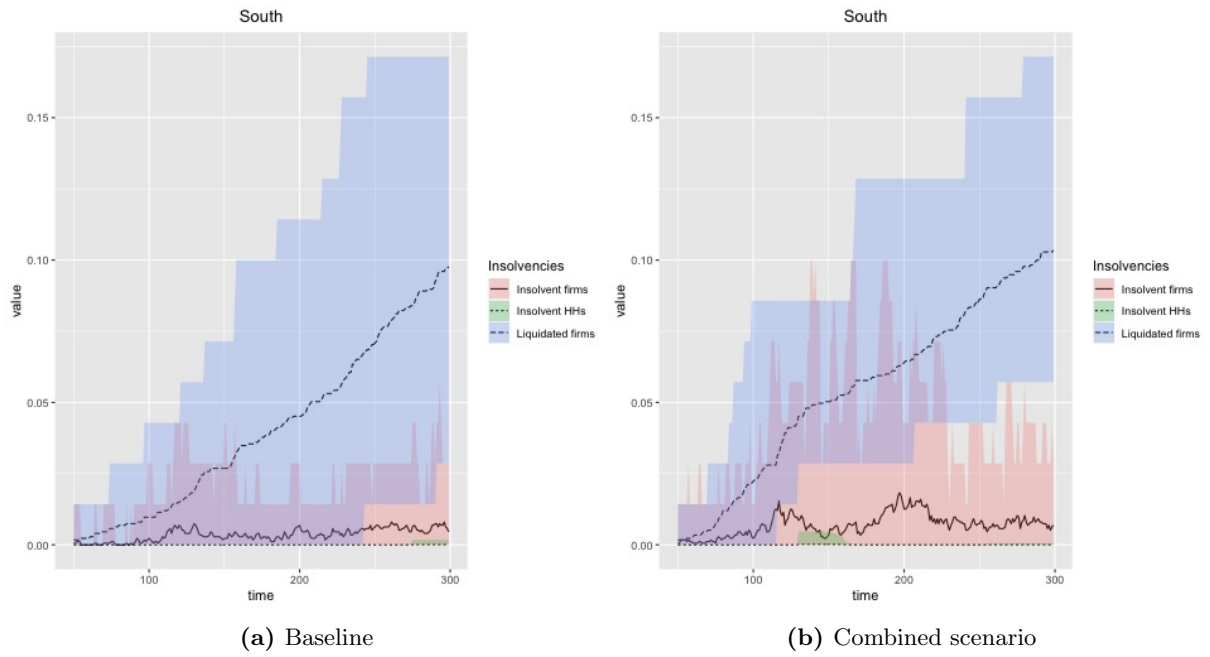
**Figure 29:** Financial aggregates of non-financial institutions in % of GDP in the South (mean of 25 runs; shaded area: min. and max. observation)



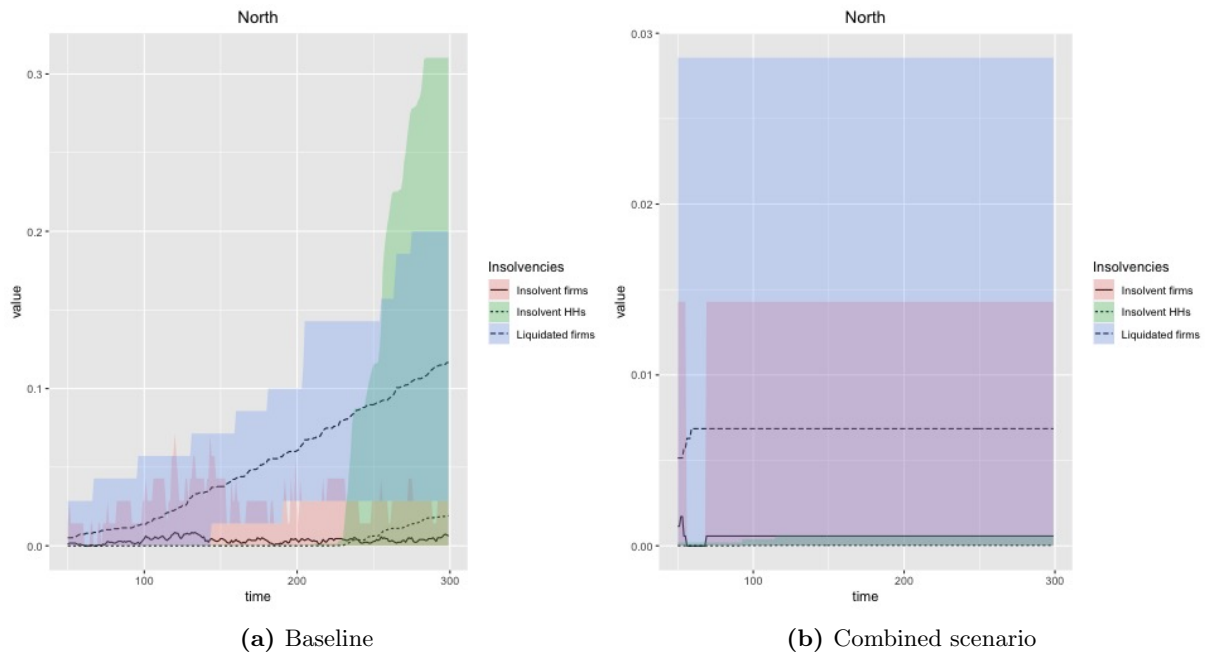
**Figure 30:** Financial aggregates of non-financial institutions in % of GDP in the North (mean of 25 runs; shaded area: min. and max. observation)



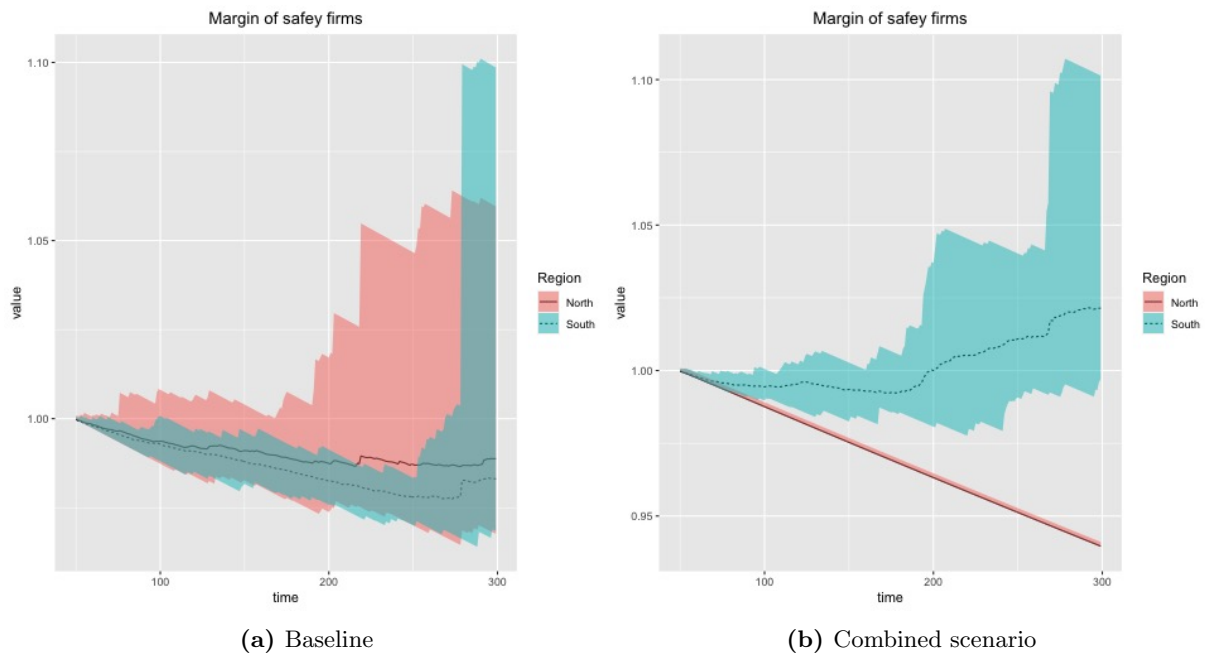
**Figure 31:** Insolvency statistics: South (mean of 25 runs; shaded area: min. and max. observation)



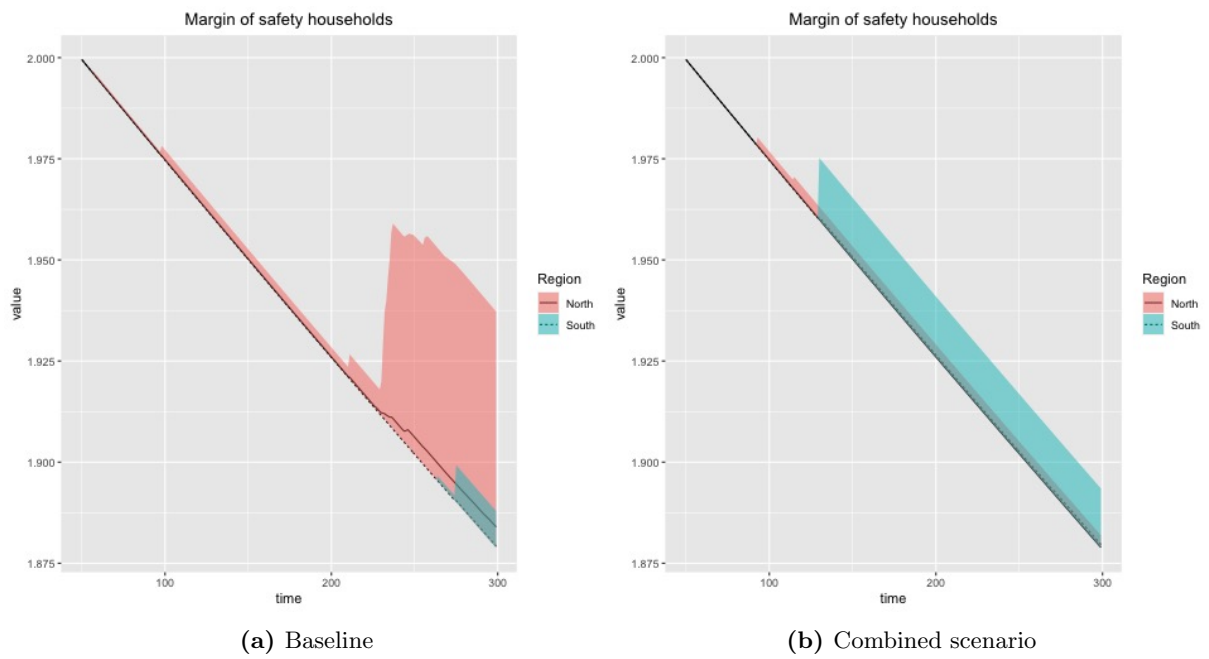
**Figure 32:** Insolvency statistics: North (mean of 25 runs; shaded area: min. and max. observation)



**Figure 33:** Margins of safety for firms (mean of 25 runs; shaded area: min. and max. observation)



**Figure 34:** Margins of safety for households (mean of 25 runs; shaded area: min. and max. observation)





seem to follow unsustainable trends. A potential reason for the seeming stability despite these potentially destabilizing underlying trends could be the absence of a large shock such as the burst of the U.S. real estate bubble in 2007/2008 and the subsequent international repercussion effects created by international financial linkages. Furthermore it can be down to limitations in the modeling approach, which does not include a market for financial assets and abstracts from trade relationships with the rest of the world (for the latter see Gräbner-Radkowsch *et al.*, 2022). Finally, these results are to some extent preliminary as further sensitivity analysis and robustness checks should be carried out in the future. All of these issues point towards a fruitful avenue for future research.

## Acknowledgements

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## A Parameters and starting values

Table 1: Parameters

Parameter	Value	Comments
$R$	2	number of regions $r$ ('North', 'South')
$H_r$	5000	number of households $h$ in each region $r$
$F_r^c$	40	number of consumption good firms $f^c$ in each region $r$
$F_r^k$	30	number of capital good firms $f^k$ in each region $r$
$B_r$	40	number of banks $b$ in each region $r$
$distance_r$	5.0	distance between regions $r$
$size_r$	100.0	size of each region $r$
$n$	100	maximum amount of goods purchased at once
$\lambda$	0.25	adaptive expectations parameter
$\mu_y$	0.5	weight of distance in purchasing decision
$\nu$	0.05	desired inventory ratio of firms
$\mu_L$	0.005	weight of distance in loan decision
$\kappa$	0.2	capital productivity
$l_{k,r}$	480.0	capital-labor-ratio
$\tau_f$	0.9	firm profit distribution parameter
$b_1$	0.01	wage bargaining parameter
$u_f^{ref}$	0.07	reference rate of unemployment firms
$u_g^{ref}$	0.07	reference rate of unemployment governments
$\bar{u}$	0.8	normal rate of capacity utilization*
$\bar{r}$	0.04345	normal rate of return on capital*
$\gamma_1$	0.02	investment demand parameter*
$\gamma_2$	0.001	investment demand parameter
$\delta$	0.03	rate of depreciation of the capital stock
$\tau_r^w$	0.15	wage income tax rate
$\tau_r^{va}$	0.1	value-added tax rate
$\tau_r^c$	0.3	corporate tax rate
$\tau_r^r$	0.5	tax rate on profit income
$\rho_f$	0.001	mark-up adjustment factor firms
$\rho_b$	0.001	mark-up adjustment factor banks
$i_D$	0.001	interest rate on deposits
$\psi_f$	0.1	financial buffer variable firms
$\psi_g$	0.1	financial buffer variable governments
$c_0$	35	consumption parameter (autonomous)
$c_1$	0.8	consumption parameter (income)
$c_2$	0.03	consumption parameter (wealth)
$res$	0.02	reserve requirement ratio
$\tau_b$	0.1	bank distributed profits parameter
$\zeta_1$	0.00025	margin of safety parameter
$\zeta_2$	0.05	margin of safety parameter

\* See [Caiani et al. \(2016\)](#).

**Table 2:** Parameters (contd.)

Parameter	Value	Comments
$n_{balance}$	12	number of periods until insolvency declaration
$\chi$	0.1	liquidation price discount
$i_{D,CB}$	0.0	interest rate on central bank deposits
$i_{L,CB}$	0.005/12	interest rate on central bank loans
$i_g$	0.015/12	interest rate on government bonds
$g_0$	12000	autonomous government spending
$g_1$	1.0	government expenditure parameter
$\tau_u$	0.85	unemployment benefits parameter
$\tau_{soc}$	1.5	social security benefits parameter
$\xi_b$	1	loan term central bank and interbank loans
$\xi_{f,h}$	120	loan term bank loans to households and firms
$\xi_g$	120	loan term government bonds

**Table 3:** Starting values

Parameter	Value	Comments
$s_{f,r,t}^e$	8000	sales expectations of firms
$i_{b,r}^o$	0.025/12	interest rate offered to households and firms
$inv_{f,r}$	0	inventory of firms
$k_{f,r}$	30000	capital stock of firms
$m_{f,r}$	0.6	mark-up of firms
$i_{L,b,r}$	0.025	interest rate on firm and household loans
$\theta_{b,r,t}^f$	1.0	margin of safety parameter applied to firms
$\theta_{b,r,t}^h$	2.0	margin of safety parameter applied to households
$w_r$	100.0	wage rate
$m_{b,r}$	3.0	mark-up of banks
$D_{h,r}$	10.0	deposit households
$D_{f,r}$	300.0	deposit firms
$D_{b,r}$	300.0	equity deposit banks

**Table 4:** Scenario parameters

Parameter	Value	Comments
$\delta_g$	0.001	change in desired capital stock growth in the South
$\delta_l$	0.001	rate of increase capital-labor ratio in the North
$\delta_b$	0.01	increase in bargaining power in the South

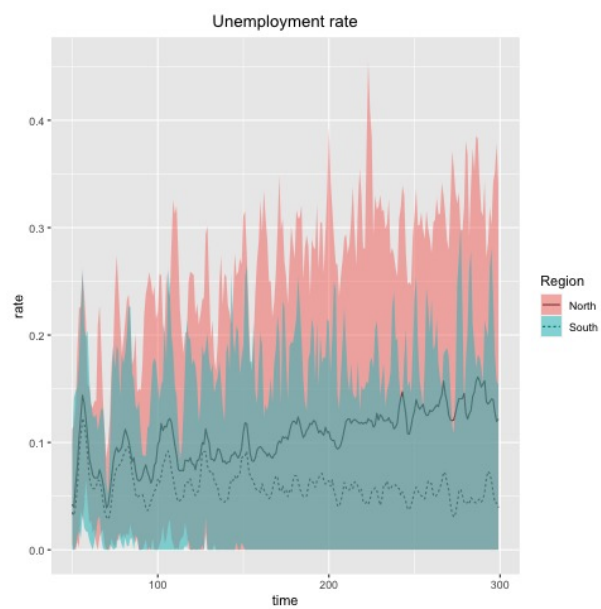
## B Baseline scenario without fiscal rule

In order to examine the impact of the fiscal deficit rule, which requires governments to try to keep their fiscal deficit within 3% of GDP, figure 35 compares the initial baseline scenario with the same baseline scenario run without that fiscal rule. It shows that dropping the fiscal rule reduces the maximum observed unemployment rate in the North significantly, though some difference compared to the South still remains.

**Figure 35:** Unemployment rate (mean of 25 runs; shaded area: min. and max. observation)



(a) Baseline



(b) Baseline without fiscal rule